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CONTENTS.

REPORTS ON THE STATE OF SCIENCE.

CONTENTS.

CONTENTS.

TRANSACTIONS OF THE SECTIONS.

[*An asterisk * indicates that the title only is given. The mark † indicates the same, but with a reference to the Journal or Newspaper in which it is published* in extenso.]

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

THURSDAY, AUGUST 1.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

DEPARTMENT OF MATHEMATICS.

Department of Astronomy and Cosmical Physics.

Section B.—CHEMISTRY.

THURSDAY, AUGUST 1.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

MONDAY, AUGUST 5.

TUESDAY, AUGUST 6.

Section D.—ZOOLOGY.

THURSDAY, AUGUST 1.

SECTION E.—GEOGRAPHY.

THURSDAY, AUGUST 1.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

TUESDAY, AUGUST 6.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

THURSDAY, AUGUST 1.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

TUESDAY, AUGUST 6.

Section G.—ENGINEERING.

THURSDAY, AUGUST 1.

SECTION I.—PHYSIOLOGY.

THURSDAY, AUGUST 1.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

TUESDAY, AUGUST 6.

SECTION K.—BOTANY.

THURSDAY, AUGUST 1.

SECTION L.—EDUCATIONAL SCIENCE.

THURSDAY, AUGUST 1.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

TUESDAY, AUGUST 6.

EVENING DISCOURSES.

FRIDAY, AUGUST 2.

MONDAY, AUGUST 5.

LIST OF PLATES.

OFFICERS AND COUNCIL, 1907-1908.

PATRON.

HIS MAJESTY THE KING.

VICE-PATRON FOR THE MEETING AT DUBLIN.

His Excellency the LORD LIEUTENANT OF IRELAND.

PRESIDENT.

Sir DAVID GILL, K.C.B., LL.D., D.Sc., F.R.S., Hon. F.R.S.E.

VICE-PRESIDENTS.

His Grace the Duke of Rutland, Lord Lieutenant of Leicestershire.
Richard Dalgliesh, J.P., D.L., High Sheriff of Leicestershire.
Sir Edward Wood, J.P., Mayor of Leicester.
The Right Hon. the Earl of Dysart
The Right Hon. the Earl Howe, G.C.V.O.
The Right Rev. the Lord Bishop of Peterborough, D.D.
The Right Rev. the Bishop of Leicester, D.D.
Sir Oliver Lodge, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham.
Herbert Ellis, President of the Leicester Literary and Philosophical Society.

PRESIDENT ELECT.

Francis Darwin, M.A., M.B., F.R.S., F.L.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord Mayor of Dublin.
The Right Hon. the Lord Chancellor of Ireland.
The Right Hon. the Chief Secretary to the Lord Lieutenant of Ireland.
His Majesty's Lieutenant for the County of Dublin.
The Chancellor of the University of Dublin.
The Chancellor of the Royal University of Ireland.
The Provost of Trinity College, Dublin.
The President of University College, Dublin.
The Right Hon. Viscount Iveagh, K.P.
The President of the Royal Dublin Society.
The President of the Royal Irish Academy.
The Vice-Chancellor of the University of Dublin.
The Vice-Chancellor of the Royal University of Ireland.
The Vice-President of the Department of Agriculture and Technical Instruction.

GENERAL TREASURER.

Professor John Perry, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Major P. A. MacMahon, R.A., D.Sc., F.R.S.
Professor W. A. Herdman, D.Sc., F.R.S.

ASSISTANT SECRETARY.

A. Silva White, Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. Stewardson, Burlington House, London, W.

LOCAL TREASURERS FOR THE MEETING AT DUBLIN.

The Hon. Mr. Justice Dodd.
Sir James Creed Meredith, LL.D.
Laurence A. Waldron, M.P.
William M. Murphy, J.P.

LOCAL SECRETARIES FOR THE MEETING AT DUBLIN.

Joseph McGrath, LL.D.
John Mulligan, J.P.
Professor W. H. Thompson, M.D., D.Sc.
Professor W. E. Thrift, M.A.

ORDINARY MEMBERS OF THE COUNCIL.

Abney, Sir W., K.C.B., F.R.S.
Anderson, Tempest, M.D., D.Sc.
Bourne, Professor G. C., D.Sc.
Bowley, A. L., M.A.
Boys, C. Vernon, F.R.S.
Brabrook, Sir Edward, C.B.
Brown, Dr. Horace T., F.R.S.
Cunningham, Professor D. J., F.R.S.
Dunstan, Professor Wyndham, F.R.S.
Dyson, Professor F. W., F.R.S.
Forsyth, Professor A. R., F.R.S.
Glazebrook, Dr. R. T., F.R.S.
Haddon, Dr. A. C., F.R.S.
Hartland, E. Sidney, F.S.A.
Hawksley, C., M.Inst.C.E.
Hogarth, D. G., M.A.
Langley, Professor J. N., F.R.S.
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Mitchell, Dr. P. Chalmers, F.R.S.
Poulton, Professor E. B., F.R.S.
Prain, Lieut.-Colonel D., C.I.E., F.R.S.
Sherrington, Professor C. S., F.R.S.
Shipley, A. E., F.R.S.
Watts, Professor W. W., F.R.S.
Woodward, Dr. A. Smith, F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord Avebury, D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Pres.R.S., F.R.A.S.
Sir Arthur W. Rücker, M.A., D.Sc., F.R.S.

PAST PRESIDENTS OF THE ASSOCIATION.

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Lord Avebury, D.C.L., F.R.S.
Lord Rayleigh, D.C.L., Pres.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir William Huggins, K.C.B., F.R.S.
Sir Archibald Geikie, K.C.B., Sec.R.S.
Lord Lister, D.C.L., F.R.S.
Sir John Evans, K.C.B., F.R.S.
Sir William Crookes, F.R.S.
Sir W. Turner, K.C.B., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir James Dewar, LL.D., F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, D.C.L., F.R.S.
Sir George Darwin, K.C.B., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.

PAST GENERAL OFFICERS OF THE ASSOCIATION.

F. Galton, D.C.L., F.R.S.
P. L. Sclater, Ph.D., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
A. Vernon Harcourt, F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Prof. E. A. Schäfer, F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.

AUDITORS.

Sir Edward Brabrook, C.B.
Professor H. McLeod, F.R.S.

INDEX TO RULES.

RULES OF
THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester*, 1907.]

CHAPTER I.

Objects and Constitution.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress. Objects.

The Association contemplates no invasion of the ground occupied by other Institutions.

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members. Constitution.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association. Annual Meetings.

CHAPTER II.

The General Committee.

1. The General Committee shall be constituted of the following persons: Constitution.

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(b) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(a) Vice-Presidents and Secretaries of the Sections.
(b) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(c) Delegates nominated by the Affiliated Societies.
(d) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission.

2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings.

3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee

Functions.

4. The General Committee shall

(i) Receive and consider the report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

CHAPTER III.

Committee of Recommendations.

1. The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association and the President of each Section at the Annual Meeting, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years. Constitution.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted. Functions.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting. Procedure.

CHAPTER IV.

Research Committees.

Procedure.

1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

Constitution.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee

appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required. GRANTS. (*a*) Drawn by Chairman.

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants. (*b*) Expire on June 30.

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then either return the balance of the grant, if any, which remains unexpended, or, if further expenditure be contemplated, apply for leave to retain the balance. (*c*) Accounts, and balance in hand.

When application is made for a Committee to be re-appointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired. (*d*) Additional Grants.

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members. (*e*) *Caveat.*

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct. Disposal of specimens, apparatus, &c.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

Chapter V.

The Council.

Constitution. 1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association. Elections.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(a) Three of the Members who have served for the longest consecutive period, and

(b) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place. Any member of the General Committee may propose another member thereof for election as one of these two members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five members at least require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff.

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

Chapter VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an *interim* statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance sheet of the Funds of the Association.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee. Audit.

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. Expenditure.

4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. Cheques.

Chapter VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees.

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

CHAPTER IX.

The Work of the Sections.

THE SECTIONS. 1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers. 2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms. 3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

SECTIONAL COMMITTEES. 4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following:—

Constitution.

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting:

Provided always that—

Privilege of Old Members. (*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation. (*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

EXECUTIVE FUNCTIONS

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee; and they shall report such action to the Sectional Committee at its next meeting.

Of President,

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise.

and of Recorder.

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee.

Organising Committee.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting.

Each Organising Committee shall hold such Meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section.

Papers and Reports.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required: to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors; and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

Admission of Members and Associates.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. Applications.

Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion. Obligations.

2. All Members are eligible to any office in the Association. Conditions and Privileges of Membership.

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound.

Corresponding Members.

3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions.

4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report.

5. The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price; and Associates for a year shall be entitled to purchase, at the same price, the volume for that year.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Corresponding Societies are constituted as follows:

Affiliated Societies.

1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

Associated Societies.

(ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society. Applications.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable. CORRESPONDING SOCIETIES COMMITTEE.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee. Procedure.

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association.

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairman, and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference. CONFERENCE OF DELEGATES.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the discussions. Procedure and Functions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations. Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

Table showing the Places and Dates of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Foundation.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
VISCOUNT MILTON, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S., F.R.S.E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S., F.R.S.E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S., F.R.S.E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich. Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford. OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University. Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S., F.R.S.E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S., F.R.S.E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S., F.R.S.E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman Esq., M.D.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S., F.R.S.E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

Presidents	Vice-Presidents	Local Secretaries
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S., F.R.S.E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley. Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S. F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S., F.R.S.E. Professor Allman, M.D., LL.D., F.R.S.L., F.R.S.E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.

ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau. Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.

WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C., Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieutenant of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford The Mayor of Oxford Sir W. R. Anson, D.C.L., Warden of All Souls College Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet. Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, Bart., D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.
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PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.
PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc., D.C.L., LL.D., F.R.S. BRADFORD, September 5, 1900.	The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Lord Masham His Worship the Mayor of Bradford The Hon. H. E. Butler, Lord of the Manor, Bradford Sir Alexander Binnie, M.Inst.C.E., F.G.S. Professor A. W. Rücker, M.A., D.Sc., Sec.R.S. Dr. T. E. Thorpe, Sc.D., F.R.S., Pres.C.S. Principal N. Bodington, Litt D., Vice-Chancellor of the Victoria University Professor L. C. Miall, F.R.S.	Ramsden Bacchus, Esq. J. E. Fawcett, Esq., J.P. Frederick Stevens, Esq.
PROFESSOR A. W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S. GLASGOW, September 11, 1901.	The Right Hon. the Earl of Glasgow, G.C.M.G. The Right Hon. the Lord Blythswood, LL.D., D.L. The Right Hon. the Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. Samuel Chisholm, Esq., the Hon. the Lord Provost of Glasgow Very Rev. R. Herbert Story, D.D., LL.D., Principal of the University of Glasgow Sir John Maxwell Stirling-Maxwell, Bart., M.P., D.L. Sir Andrew Noble, K.C.B., D.C.L., F.R.S. Sir Archibald Geikie, D.C.L., LL.D., F.R.S. Sir W. T. Thiselton-Dyer, K.C.M.G., C.I.E., F.R.S. James Parker Smith, Esq., M.P., D.L. John Inglis, Esq., LL.D. Professor John Cleland, M.D., LL.D., D.Sc., F.R.S.	Sir J. D. Marwick, LL.D., D.L., F.R.S.E. Professor John Young, M.D. Professor Magnus Maclean, D.Sc., F.R.S.E.

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PROFESSOR JAMES DEWAR, M.A., LL.D., D.Sc., F.R.S. BELFAST, September 10, 1902.	His Grace the Duke of Abercorn, K.G., H.M. Lieutenant of the County of Donegal The Marquis of Londonderry, K.G., H.M. Lieutenant of the City of Antrim Belfast Sir Francis Macnaghten, Bart., H.M. Lieutenant of the County of The Right Hon. the Earl of Shaftesbury, D.L. The Right Hon. the Earl of Rosse, K.P., D.C.L., LL.D., F.R.S. The Right Hon. Thomas Sinclair, D.Lit. Sir William Quartus Ewart, Bart., M.A. The Lord Mayor of Belfast The President of Queen's College, Belfast Professor E. Ray Lankester, M.A., F.R.S. Professor Peter Redfern, M.D.	John Brown, Esq., F.R.S. Godfrey W. Ferguson, Esq. Professor Maurice FitzGerald, B.A.
SIR NORMAN LOCKYER, K.C.B., LL.D., F.R.S., Correspondant de l'Institut de France SOUTHPORT, September 9, 1903.	The Right Hon. the Earl of Derby, K.G., G.C.B. The Right Hon. the Earl of Crawford and Balcarres, K.T., LL.D., F.R.S. The Right Hon. the Earl Spencer, K.G., LL.D., Chancellor of the Victoria University The Right Hon. the Earl of Sefton The Right Hon. the Earl of Lathom Sir Henry Roscoe, B.A., Ph.D., LL.D., D.C.L., F.R.S. Sir George A. Pilkington Alfred Hopkinson, Esq., LL.D., K.C., Vice-Chancellor of the Victoria University T. T. L. Scarisbrick, Esq., Mayor of Southport E. Marshall Hall, Esq., K.C., M.P. for Southport Charles H. B. Hesketh, Esq. Charles Scarisbrick, Esq., J.P. Charles Weld Blundell, Esq.	Harold Brodrick, Esq., M.A. J. Ernest Jarratt, Esq.
The RIGHT HON. A. J. BALFOUR, D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh CAMBRIDGE, August 17, 1904.	His Grace the Duke of Devonshire, K.G., LL.D., F.R.S., Chancellor of the University of Cambridge Alexander Peckover, Esq., LL.D., Lord Lieutenant of Cambridgeshire Arthur Hall, Esq., M.A., D.L., High Sheriff of Cambridgeshire and Huntingdonshire The Right Rev. the Lord Bishop of Ely, D.D. The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, D.C.L., LL.D., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. The Rev. F. H. Chase, D.D., Vice-Chancellor of the University and President of Queen's College, Cambridge The Very Rev. H. Montagu Butler, D.D., Master of Trinity Mrs. Sidgwick, Principal of Newnham College, Cambridge J. H. Chesshyre Dalton, Esq., M.D., Mayor of Cambridge Robert Stephenson, Esq., Chairman of the Cambridgeshire County Council Joseph Martin, Esq., Chairman of the Isle of Ely County Council P. H. Young, Esq., Deputy Mayor of Cambridge	S. R. Ginn, Esq., D.L. A. Hutchinson, Esq., M.A. A. C. Seward, Esq., M.A., F.R.S. S. Skinner, Esq., M.A. E. L. Whitehead, Esq., M.A.

PROFESSOR G. H. DARWIN, M.A., LL.D., Ph.D., F.R.S. SOUTH AFRICA, August 15, 1905.	His Excellency the Right Hon. the Earl of Selborne, G.C.M.G., High Commissioner for South Africa The Right Hon. Lord Milner, G.C.B., G.C.M.G., late High Commissioner for South Africa His Excellency the Hon. Sir Walter F. Hely-Hutchinson, G.C.M.G., Governor of Cape Colony His Excellency Colonel Sir Henry E. McCallum, K.C.M.G., R.E., Governor of Natal His Excellency Captain the Hon. Sir Arthur Lawley, K.C.M.G., Lieutenant-Governor, Transvaal His Excellency Major Sir H. J. Goold-Adams, K.C.M.G., Lieutenant-Governor, Orange River Colony His Honour Sir W. H. Milton, K.C.M.G., Administrator of Southern Rhodesia. Sir Charles H. T. Metcalfe, Bart., M.A. Sir David Gill, K.C.B., LL.D., F.R.S., H.M. Astronomer, Cape Colony Theodore Reunert, M.Inst.C.E. The Mayor of Cape Town The Mayor of Johannesburg The President of the Philosophical Society of South Africa The Mayor of Durban The Mayor of Pietermaritzburg The Mayor of Bloemfontein The Mayor of Pretoria The Mayor of Kimberley The Mayor of Bulawayo	*Cape Town:—* Professor J. C. Beattie, D.Sc., F.R.S.E. E. J. Cattell, J.P. J. R. Finch. Rev. Wm. Flint, D.D. E. H. Jones. W. L. Sclater, M.A. *Johannesburg:—* W. E. Cursons F. Rowland. *Central Organising Committee for South Africa:—* *Chairman.*—Sir David Gill, K.C.B., F.R.S. *Hon. Secretaries.*—J. D. F. Gilchrist, M.A., Ph.D. (Cape Town); W. Cullen (Johannesburg).
PROFESSOR E. RAY LANKESTER, M.A., LL.D., D.Sc., F.R.S., F.L.S., Director of the Natural History Departments of the British Museum. YORK, August 1, 1906.	His Grace the Archbishop of York, D.D., D.C.L., M.A. The Right Hon. the Lord Mayor of York The High Sheriff of Yorkshire The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S. The Right Hon. the Earl of Feversham The Right Rev. the Lord Bishop of Ripon, D.D., D.C.L. The Right Hon. Lord Avebury, D.C.L., LL.D., F.R.S. The Right Hon. Lord Wenlock, G.C.S.I., G.C.I.E., K.C.B. Sir Hugh Bell, Bart. Sir George S. Gibb Tempest Anderson, M.D., D.Sc., President of the Yorkshire Philosophical Society. John Stephenson Rowntree	Henry Craven. C. E. Elmhirst.
SIR DAVID GILL, K.C.B., LL.D., F.R.S., Hon. F.R.S.E. LEICESTER, July 31, 1907.	His Grace the Duke of Rutland, Lord Lieutenant of Leicestershire Richard Dalgliesh, J.P., D.L., High Sheriff of Leicestershire Sir Edward Wood, J.P., Mayor of Leicester The Right Hon. the Earl of Dysart The Right Hon. the Earl Howe, G.C.V.O. The Right Rev. the Lord Bishop of Peterborough, D.D. The Right Rev. the Bishop of Leicester, D.D. Sir Oliver Lodge, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham Herbert Ellis, President of the Leicester Literary and Philosophical Society	Alfred Colson, M.Inst.C.E. E. V. Hiley.

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1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath.........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford......	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol......	Prof. W. E. Ayrton, F.R.S. ...	A. P. Chattock, J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1900. Bradford...	Dr. J. Larmor, F.R.S.—*Dep. of Astronomy*, Dr. A. A. Common, F.R.S.	P. H. Cowell, A. Fowler, C. H. Lees, C. J. L. Wagstaffe, W. Watson, E. T. Whittaker.
1901. Glasgow ...	Major P. A. MacMahon, F.R.S. —*Dep. of Astronomy*, Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees, W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast......	Prof. J. Purser, LL.D., M.R.I.A. —*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees, Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. SouthAfrica	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr. C. H. Lees.
1906. York.........	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter, H. Dennis Taylor.
1907. Leicester...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope............................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

Date and Place	Presidents	Secretaries
1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838 Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S.......	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.

Date and Place	Presidents	Secretaries
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. Y. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S...............	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S. ...	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	P. P. Bedson, H. B. Dixon, H. F. Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

Date and Place	Presidents	Secretaries
1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S. ...	Arthur Harden, C. A. Kohn.
1897 Toronto ...	Prof. W. Ramsay, F.R.S......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol......	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.

Date and Place	Presidents	Secretaries
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Kohn, T. K. Rose, Prof. W. P. Wynne.
1900. Bradford ...	Prof. W. H. Perkin, F.R.S. ...	W. M. Gardner, F. S. Kipping, W. J. Pope, T. K. Rose.
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose.
1902. Belfast......	Prof. E. Divers, F.R.S.........	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope.
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope.
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope.
1905. South Africa	George T. Beilby	W. A. Caldecott, Dr. M. O. Forster, Prof. G. G. Henderson, C. F. Juritz.
1906. York.........	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope.
1907. Leicester ...	Prof. A. Smithells, F.R.S. ...	Dr. E. F. Armstrong, Prof. A. W. Crossley, J. H. Hawthorn, Dr. F. M. Perkin.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, H. Murray, H. E. Strickland, J. Scoular.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S. ...	F. M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A. F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S. Benson, Prof. Oldham, Prof. Ramsay
1849. Birmingham	Sir Charles Lyell, F.R.S.......	J. B. Jukes, Prof. Oldham, A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

[1] Geography was constituted a separate Section, see page lxxii.

SECTION C (*continued*).—GEOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, G. Sanders, R. H. Scott.
1858. Leeds	William Hopkins, M.A., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen ...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, F.R.S...	Prof. Harkness, E. Hull, J. W. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B., F.R.S.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.......	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, F.R.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ..	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.

Date and Place	Presidents	Secretaries
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S.	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol	W. H. Hudleston, F.R.S.	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir Archibald Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.
1900. Bradford ...	Prof. W. J. Sollas, F.R.S. ...	H. L. Bowman, Rev. W. L. Carter, G. W. Lamplugh, H. W. Monckton.
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton.
1902. Belfast	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton, J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton.
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman, J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.........	G. W. Lamplugh, F.R.S.	H. L. Bowman, Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester ...	Prof. J. W. Gregory, F.R.S....	Dr. F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh .	Prof. Graham....................	W. Yarrell, Prof. Burnett.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lxx.

Date and Place	Presidents	Secretaries

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S. ...	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxx.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S., F.R.S.E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. E. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. E. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.

Date and Place	Presidents	Secretaries
1864. Bath	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham[1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh .	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anth.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.

[1] The title of Section D was changed to Biology.

Date and Place	Presidents	Secretaries
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, F.R.S.—*Dep. of Anat. & Physiol.*, F. M. Balfour, F.R.S.—*Dep. of Anthropol.*, F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	R. Owen, F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S. —*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S., F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.
1888. Bath.........	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff......	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.

[1] Anthropology was made a separate Section, see p. lxxviii.

Date and Place	Presidents	Secretaries
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol.	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.
1900. Bradford ...	Dr. R. H. Traquair, F.R.S. ...	W. Garstang, J. G. Kerr, T. H. Taylor, Swale Vincent.
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr, J. Rankin, J. Y. Simpson.
1902. Belfast......	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson.
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson, Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson, Dr. H. W. M. Tims.
1905. South Africa	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Dr. H. W. M. Tims, Prof. J. Y. Simpson.
1906. York.........	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims.
1907. Leicester ...	Dr. W. E. Hoyle, M.A.........	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

[1] Physiology was made a separate Section, see p. lxxix.
[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries
	SECTION E.—PHYSIOLOGY.	
1841. Plymouth ...	P. M. Roget, M.D., Sec. R.S.	J. Butter, J. Fuge, R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	T. K. Chambers, W. P. Ormerod.
	PHYSIOLOGICAL SUBSECTIONS OF SECTION D.	
1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir B. Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lxiv.]

	ETHNOLOGICAL SUBSECTIONS OF SECTION D.	
1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

	SECTION E.—GEOGRAPHY AND ETHNOLOGY.	
1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, E. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.

[1] Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lxvii). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lxvi.

Date and Place	Presidents	Secretaries
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres.R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham.	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter......	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.

Date and Place	Presidents	Secretaries
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J S. O'Halloran, E. Ravenstein, Rev. G. A. Smith.
1886. Birmingham.	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto ...	J. Scott Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol......	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.
1900. Bradford...	Sir George S. Robertson, K.C.S.I.	H. N. Dickson, E. Heawood, E. R. Wethey.
1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson, E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast ...	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm, E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport	Capt. E. W. Creak, R.N., C B., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.........	E. Heawood, Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. SouthAfrica	Adm. Sir W. J. L. Wharton, R.N., K.C.B, F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson, H. Y. Oldham.
1906. York.........	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood, Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.
1907. Leicester...	George G. Chisholm, M.A. ...	E. Heawood, O. J. R. Howarth, E. A. Reeves, T. Walker.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.

Date and Place	Presidents	Secretaries
1837. Liverpool...	Rt. Hon. Lord Sandon.........	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham.	Henry Hallam, F.R.S..........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford......	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham.	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. P. G. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines..................	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	W. Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham.	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.

Date and Place	Presidents	Secretaries
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872 Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D. ...	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham.	J. B. Martin, M.A., F.S.S. ...	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff. ..	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford......	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol... ..	J. Bonar, M.A., LL.D..........	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.

Date and Place	Presidents	Secretaries
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
1900. Bradford ...	Major P. G. Craigie, V.P.S.S.	A. L. Bowley, E. Cannan, S. J. Chapman, F. Hooper.
1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan, S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley, Prof. S. J Chapman, Dr. A. Duffin
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley, Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.........	A. L. Bowley, M.A.	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester...	Prof. W. J. Ashley, M.A.......	Prof. S. J. Chapman, D. H. Macgregor, H. O. Meredith, T. S. Taylor.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham.	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.........	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich ...	William Cubitt, F.R.S..........	John Head, Charles Manby.
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, F.R.S. ...	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge.	William Fairbairn, F.R.S. ...	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle .	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.

Date and Place	Presidents	Secretaries
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham.	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman. E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E..........	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F Churton, H. T. Wood.
1883. Southport .	J. Brunlees, Pres. Inst. C.E. ...	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham.	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne.	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff.....	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.

Date and Place	Presidents	Secretaries
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E. ...	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol......	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.
1900. Bradford[1]	Sir Alex. R. Binnie, M.Inst. C.E.	Prof. T. H. Beare, C. F. Charnock, Prof. S. Dunkerley, W. A. Price.

SECTION G.—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W.E. Dalby, W. A. Price.
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price, J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall W. A. Price.
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price.
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall, Prof. H. Payne, E. Williams.
1906. York.........	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price, J. Triffit.
1907. Leicester ...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price, H. E. Wimperis.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham.	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.
1897. Toronto ...	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.
1898. Bristol......	E. W. Brabrook, C.B.	H. Balfour, J. L. Myres, G. Parker.
1899. Dover	C. H. Read, F.S.A.	H. Balfour, W. H. East, Prof. A. C. Haddon, J. L. Myres.

[1] The title of Section G was changed to Engineering.

Date and Place	Presidents	Secretaries
1900. Bradford ...	Prof. John Rhys, M.A.	Rev. E. Armitage, H. Balfour, W. Crooke, J. L. Myres.
1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres.
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres.
1903. Southport	Prof. J. Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres.
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres.
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland.
1906. York.........	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize, H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ...	D. G. Hogarth, M.A............	C. J. Billson, E. N. Fallaize, H. S Kingsford, Dr. F. C. Shrubsall.

SECTION I.—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool...	Dr. W. H. Gaskell, F.R.S. ...	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.
1899. Dover	J. N. Langley, F.R.S.	Dr. Howden, Dr. L. E. Shore, Dr. E. H. Starling.
1901. Glasgow ...	Prof. J. G. McKendrick, F.R S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson.
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne, Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft, Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft, Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.
1906. York.........	Prof. F. Gotch, F.R.S.	J. Barcroft, Dr. J. M. Hamill, Prof. J. S. Macdonald, Dr. D. S. Long.
1907. Leicester ...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft, Prof J. S. Macdonald, Dr. A. Warner.

SECTION K.—BOTANY.

1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
1897. Toronto ...	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.
1898. Bristol......	Prof. F. O. Bower, F.R.S. ...	A. C. Seward, H. Wager, J. W. White.
1899. Dover	Sir George King, F.R.S.	G. Dowker, A. C. Seward, H. Wager.
1900. Bradford ...	Prof. S. H. Vines, F.R.S.......	A. C. Seward, H. Wager, W. West.
1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward, H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager, R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager, R. H. Yapp.

Date and Place	Presidents	Secretaries
1904. Cambridge	Francis Darwin, F.R.S.	Dr. F. F. Blackman, A. G. Tansley, H. Wager, T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp.
1906. York.........	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G Tansley, Prof. R. H. Yapp.
1907. Leicester ...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley, Prof. R. H. Yapp.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers.
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller, R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins, J. R. Whitton.
1906. York.........	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller, Hugh Richardson.
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory, J. S. Laver, Hugh Richardson.

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES.

Date and Place	Chairmen	Secretaries
1885. Aberdeen...	Francis Galton, F.R.S....... ..	Prof. Meldola.
1886. Birmingham	Prof. A. W. Williamson, F.R.S.	Prof. Meldola, F.R.S.
1887. Manchester	Prof. W. Boyd Dawkins, F.R.S.	Prof. Meldola, F.R.S.
1888. Bath.........	John Evans, F.R.S.	Prof. Meldola, F.R.S.
1889. Newcastle-upon-Tyne	Francis Galton, F.R.S..........	Prof. G. A. Lebour.
1890. Leeds	G. J. Symons, F.R.S.	Prof. Meldola, F.R.S.
1891. Cardiff	G. J. Symons, F.R.S.	Prof. Meldola, F.R.S.
1892. Edinburgh	Prof. Meldola, F.R.S.	T. V. Holmes.
1893. Nottingham	Dr. J. G. Garson	T. V. Holmes.
1894. Oxford	Prof. Meldola, F.R.S.	T. V. Holmes.
1895. Ipswich ...	G. J. Symons, F.R.S.	T. V. Holmes.
1896. Liverpool...	Dr. J. G. Garson	T. V. Holmes.
1897. Toronto ...	Prof. Meldola, F.R.S.	J. Hopkinson.
1898. Bristol	W. Whitaker, F.R.S.	T. V. Holmes.
1899. Dover	Rev. T. R. R. Stebbing, F.R.S.	T. V. Holmes.
1900. Bradford ...	Prof. E. B. Poulton, F.R.S. ...	T. V. Holmes.
1901. Glasgow ...	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902. Belfast......	Prof. W. W. Watts, F.G.S. ...	E. J. Bles.
1903. Southport	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London ...	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York.........	Sir Edward Brabrook, C.B....	F. W. Rudler.
1907. Leicester ...	H. J. Mackinder, M.A.........	F. W. Rudler, I.S.O.

EVENING DISCOURSES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham.	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their Changes of Form.
	G. B. Airy, F.R.S., Astronomer Royal	Total Solar Eclipse of July 28 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.............	Correlation of Physical Forces.

Date and Place	Lecturer	Subject of Discourse
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	*Electrical Discharges in highly rarefied Media.*
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham.	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S......	The Results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.........	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ..	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S......	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S.........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The 'Challenger' Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The New Element, Gallium.

Date and Place	Lecturer	Subject of Discourse
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S.........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E.........	The Great Ocean Basins.
1886. Birmingham.	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff......	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ...	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
1897. Toronto ...	Prof. W. C. Roberts-Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S...................	Earthquakes and Volcanoes.
1898. Bristol......	Prof. W. J. Sollas, F.R.S. ..	Funafuti: the Study of a Coral Island.
	Herbert Jackson	Phosphorescence.
1899. Dover	Prof. Charles Richet...........	La vibration nerveuse.
	Prof. J. Fleming, F.R.S.	The Centenary of the Electric Current.

Date and Place	Lecturer	Subject of Discourse
1900. Bradford ...	Prof. F. Gotch, F.R.S.	Animal Electricity.
	Prof. W. Stroud.	Range Finders.
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	F. Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.
1903. Southport	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. South Africa:		
Cape Town ...	Prof. E. B. Poulton, F.R.S. ...	W. J. Burchell's Discoveries in South Africa.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban ...	Douglas W. Freshfield.........	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritzburg	Col. D. Bruce, C.B., F.R.S....	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S. ...	The Distribution of Power.
	Prof. J. O. Arnold..............	Steel as an Igneous Rock.
Pretoria ...	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein...	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley ...	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo ...	D. Randall-MacIver	The Ruins of Rhodesia.
1906. York.........	Dr. Tempest Anderson.........	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.
1907. Leicester ...	W. Duddell, F.R.S.	The Ark and the Spark in Radio-telegraphy.
	Dr. F. A. Dixey..................	Recent Developments in the Theory of Mimicry.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Lecture
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B....	A Journey through Africa.
1877. Plymouth...	W. H. Preece.....................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.

Date and Place	Lecturer	Subject of Lecture
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York.........	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath.........	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff......	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford......	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison.................	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol	Prof. E. B. Poulton, F.R.S. ...	The ways in which Animals Warn their Enemies and Signal to their Friends.
1900. Bradford ...	Prof. S. P. Thompson, F.R.S.	Electricity in the Industries.
1901. Glasgow ...	H. J. Mackinder, M.A..........	The Movements of Men by Land and Sea.
1902. Belfast......	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.
1906. York.........	Prof. S. P. Thompson, F.R.S.	The Manufacture of Light.
1907. Leicester ...	Prof. H. A. Miers, F.R.S.......	The Growth of a Crystal.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres.R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	945 0 0	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
419	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting

¶ Including 848 Members of the South African Association.

ANALYSIS OF ATTENDANCES AT THE ANNUAL MEETINGS, 1831-1906.

[*The total attendances for the years* 1832, 1835, 1843, *and* 1844 *are unknown.*]

Average attendance at 72 *Meetings* : 1855.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 3 Meetings beginning during *July, between* 1841 *and* 1851	947
Average attendance at 28 Meetings beginning during *August, between* 1836 *and* 1906	1978*
Average attendance at 34 Meetings beginning during *September, between* 1831 *and* 1903	1933
Attendance at 1 Meeting held in *October, Cambridge*, 1862	1161

Meetings beginning during August and September.

Average attendance at—

4 Meetings beginning during the 1st week in *August*	(1st– 7th)	.	1905
5 ,, ,, ,, ,, 2nd ,, ,, ,,	(8th–14th)	.	2130
8 ,, ,, ,, ,, 3rd ,, ,, ,,	(15th–21st)	.	1761 †
11 ,, ,, ,, ,, 4th ,, ,, ,,	(22nd–31st)	.	2094

Average attendance at—

11 Meetings beginning during the 1st week in *September*	(1st– 7th).	2082
16 ,, ,, ,, ,, 2nd ,, ,, ,,	(8th–14th).	1860
5 ,, ,, ,, ,, 3rd ,, ,, ,,	(15th-21st).	2206
2 ,, ,, ,, ,, 4th ,, ,, ,,	(22nd-30th).	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th-21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

* Average attendance at 29 Meetings, *including* South Africa, 1905 (August 15–September 1): 1983.

† Average attendance at 9 Meetings, *including* South Africa, 1905 (August 15–September 1): 1802.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars (Lacaille)	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons....................	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)..................	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh ...	69	1	10
Tabulating Observations	9	6	3
Races of Men.....................	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments..	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers.....................	26	17	6
Marine Zoology..................	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education.........	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of) ...	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds ...	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds ...	8	1	11
Questions on Human Race ...	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation.........	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light......	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries ...	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways.......................	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks.........................	30	0	0
Report on Zoological Nomenclature.........................	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds ...	5	3	8
Marine Testacea (Habits of) .	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells......	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia 10		0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument.........1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh...........	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces ...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall...	10	0	0
Physiological Action of Medicines............................	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory...	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854.........£ 75 0 0; 1855.........£500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seed	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl Series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Carols	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observation	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committe	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for Fourth Million	100	0	0
Anthropometric Committee	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards	25	0	0
High Insulation Key............	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record...............	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements..............	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record..............	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters.........................	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise..............	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives...............	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters..........................	15	0	0
Geological Record..............	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station...	25	0	0
Elimination of Nitrogen by Bodily Exercise..............	38	3	3
Exploration of Mount Kilima-njaro..................... .	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges.....................	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust.................	20	0	0
Meteorological Observatory at Chepstow.......................	25	0	0
Tidal Observations..............	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa....................	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters..........................	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds..............	20	0	0
Coagulation of Blood...........	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory.........	50	0	0
Electrical Standards...........	100	0	0
Electrolysis......................	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes.........	20	0	0
Photographs of Meteorological Phenomena....................	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel...	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record..............	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire ...	25	0	0
Registration of Type-Specimens of British Fossils......	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis ...	50	0	0
Photographs of Meteorological Phenomena....................	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave............................	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands...	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory...	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards............	25	0	0
Observations on Ben Nevis ...	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda..............	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills............................	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave	5	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart	10	0	0
Exploration in Abyssinia ...	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills.....	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut ...	50	0	0
Calibration and Comparison of Measuring Instruments ...	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electro-chemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1059	10	8

1898.

	£	s.	d.
Electrical Standards	75	0	0
Seismological Observations	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements ...	20	0	0
Action of Light upon Dyed Colours	8	0	0
Erratic Blocks	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest	10	0	0
Life-zones in British Carboniferous Rocks	15	0	0
Pleistocene Fauna and Flora in Canada	20	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	14	0	0
Index Generum et Specierum Animalium	100	0	0
Healthy and Unhealthy Oysters	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries	15	0	0
Small Screw Gauge	20	0	0
North-Western Tribes of Canada...........................	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee	25	0	0
	£1212	0	0

1899.

	£	s.	d.
Electrical Standards............	225	0	0
Seismological Observations...	65	14	8
Science Abstracts	100	0	0
Heat of Combination of Metals in Alloys	20	0	0
Radiation in a Magnetic Field	50	0	0
Calculation of certain Integrals	10	0	0
Action of Light upon Dyed Colours	4	19	6
Relation between Absorption Spectra and Constitution of Organic Substances	50	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	10	0	0
Remains of Irish Elk in the Isle of Man....................	15	0	0
Pleistocene Flora and Fauna in Canada	30	0	0
Records of Disappearing Drift Section at Moel Tryfaen ...	5	0	0
Ty Newydd Caves..............	40	0	0
Ossiferous Caves at Uphill ...	30	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Apparatus for Keeping Aquatic Organisms under Definite Physical Conditions	15	0	0
Plankton and Physical Conditions of the English Channel during 1899	100	0	0
Exploration of Sokotra	35	0	0
Lake Village at Glastonbury	50	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	35	0	0
New Edition of 'Anthropological Notes and Queries'...	40	0	0
Age of Stone Circles...........	20	0	0
Physiological Effects of Peptone	30	0	0
Electrical Changes accompanying Discharge of Respiratory Centres..............	20	0	0
Influence of Drugs upon the Vascular Nervous System...	10	0	0
Histological Changes in Nerve Cells............................	20	0	0
Micro-chemistry of Cells	40	0	0
Histology of Suprarenal Capsules	20	0	0
Comparative Histology of Cerebral Cortex	10	0	0
Fertilisation in Phyæophyceæ	20	0	0
Assimilation in Plants.........	20	0	0
Zoological and Botanical Publication	5	0	0
Corresponding Societies Committee	25	0	0
	£1430	14	2

1900.

	£	s.	d.
Electrical Standards...........	25	0	0
Seismological Observations...	60	0	0
Radiation in a Magnetic Field	25	0	0
Meteorological Observatory at Montreal	20	0	0
Tables of Mathematical Functions	75	0	0
Relation between Absorption Spectra and Constitution of Organic Bodies	30	0	0
Wave-length Tables	5	0	0
Electrolytic Quantitative Analysis	5	0	0

	£	s.	d.
Isomorphous Sulphonic Derivatives of Benzene	20	0	0
The Nature of Alloys	30	0	0
Photographs of Geological Interest	10	0	0
Remains of Elk in the Isle of Man	5	0	0
Pleistocene Fauna and Flora in Canada	10	0	0
Movements of Underground Waters of Craven	40	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	50	0	0
Migration of Birds	15	0	0
Plankton and Physical Conditions of the English Channel	40	0	0
Zoology of the Sandwich Islands	100	0	0
Coral Reefs of the Indian Region	30	0	0
Physical and Chemical Constants of Sea-Water	100	0	0
Future Dealings in Raw Produce	2	10	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	50	0	0
New Edition of 'Anthropological Notes and Queries'	40	0	0
Photographs of Anthropological Interest	10	0	0
Mental and Physical Condition of Children in Schools	5	0	0
Ethnography of the Malay Peninsula	25	0	0
Physiological Effects of Peptone	20	0	0
Comparative Histology of Suprarenal Capsules	20	0	0
Comparative Histology of Cerebral Cortex	5	0	0
Electrical Changes in Mammalian Nerves	20	0	0
Vascular Supply of Secreting Glands	10	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Com.	20	0	0
	£1072	10	0

1901.

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean	50	0	0

	£	s.	d.
Compound Ascidians of the Clyde Area	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903.

	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves	40	0	0
Underground Waters of North-west Yorkshire	40	0	0
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Com.	20	0	0
	£845	13	2

1904.

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	18	11

1905.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitramines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations on Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
AnthropometricInvestigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s.	d.
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitramines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
AnthropometricInvestigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907.

	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7

	£	s.	d.
Anthropometric Investigations in the British Isles ...	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research of South African Cycads..........................	35	0	0
Botanical Photographs.........	5	0	0
Structure of Fossil Plants ...	5	0	0
Marsh Vegetation..	15	0	0
Corresponding Societies Committee..........................	16	14	1
	£757	12	10

Report of the Council, 1906–1907.

I. The Council have expressed condolence with the widow of the late Sir MICHAEL FOSTER, whose many and conspicuous services in all the offices of the Association were highly appreciated by his colleagues.

II. Mr. FRANCIS DARWIN, F.R.S., has been nominated by the Council to fill the office of President of the Association for the year 1908–1909.

III. The following NOMINATIONS are made by the Council :—

(i) Additional Vice-Presidents of the Association for the Meeting at Leicester: His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire; Mr. Richard Dalgliesh, High Sheriff of Leicestershire; the Right Hon. the Earl of Dysart; the Right Hon. the Earl Howe; the Right Rev. the Lord Bishop of Peterborough; the Right Rev. the Bishop of Leicester; Sir Oliver Lodge.

(ii) Mr. H. J. Mackinder, Chairman, Rev. J. O. Bevan, Vice-Chairman, and Mr. F. W. Rudler, Secretary, of the Conference of Delegates of Corresponding Societies to be held at Leicester.

(iii) Members of the Corresponding Societies Committee for the ensuing year: Mr. W. Whitaker, Chairman; Mr. F. W. Rudler, Secretary; Rev. J. O. Bevan, Sir Edward Brabrook, C.B., Dr. Horace T. Brown, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. R. Stebbing, Professor W. W. Watts, and the President and General Officers of the Association.

IV. A Report has been received from the Corresponding Societies Committee, together with the list of the CORRESPONDING SOCIETIES and the titles of the more important Papers, especially of those referring to local scientific investigations, published by the Societies during the year ending May 31, 1907.

V. The following RESOLUTION has been considered by the Council and acted upon :—

From Section A.

That, in the opinion of the Committee of Section A, it is highly desirable that Sir William Hamilton's Memoirs on Dynamics, on Systems of Rays, and other Memoirs on Pure and Applied Mathematics should be republished in accessible form; and that this Resolution, if approved by the Council, be communicated to the Royal Irish Academy.

A Sub-Committee of Section A is making inquiries for the purpose of promoting the object in view.

VI. A RESOLUTION, in regard to the appointment of an Inspector of Ancient Monuments, has been considered by the Council :—

From Section H.

That the Council of the British Association be asked to impress upon His Majesty's Government the desirability of appointing an Inspector of Ancient Monuments, fully qualified to perform the duties of his office, with full powers under the Act, and with instructions to report periodically on his work with a view to publication.

The Council appointed a Committee, consisting of Sir John Evans, Sir Edward Brabrook, Mr. Sidney Hartland, Sir Norman Lockyer, and Lord Balcarres, to report on the proposal, and have received the following :—

Your Committee, in accordance with the terms of their appointment, have taken into consideration the terms of the Resolution presented to the Council from Section H, in which they fully concur. They learn that the subject has been under the consideration of the Congress of Archæological Societies, which has passed the Resolution of which a copy is annexed and of the terms of which your Committee entirely approve.

They further understand that the question of the appointment of an Inspector, in accordance with the provisions of the Ancient Monuments Protection Act, is about to be considered by the Council of the Society of Antiquaries and, in all probability, of other learned Societies. They therefore recommend that the Council of the Association should co-operate by all means in their power with these bodies in bringing the desirability of carrying out the provisions of the Act under the notice of His Majesty's Government. It appears to your Committee that the present moment is well fitted for calling attention to the matter, inasmuch as the destruction of early megalithic monuments is daily going on, and several have been absolutely destroyed.

In view of this destruction, your Committee are further of opinion that it should be an instruction to the Inspector of Ancient Monuments to prepare a list, as complete as possible, of all megalithic monuments, whether under public control or not, and that steps should be taken to secure their preservation in future.

Furthermore, your Committee are of opinion that steps ought at once to be taken to prepare a list and secure the preservation, not only of megalithic monuments, but of all ancient monuments deemed worthy of the national care; and that this cannot be effectually done without recognising a property in such monuments on the part of the nation overriding all private ownership and custody, and conferring much larger powers on the inspector, so as to prevent injury to such monuments by any person whomsoever.

This Report, having been approved by the Council, was sent with a covering letter to the Prime Minister on December 19, 1906. Furthermore, the President attached his signature to the following Memorial, drawn up by the Council of the Society of Antiquaries :—

To the Prime Minister,
The Right Hon. Sir Henry Campbell-Bannerman, G.C.B.

We, the undersigned, representing the Societies named, beg leave respectfully to represent to you that by the Act of 45 & 46 Victoria (c. 73), 1882, known as 'The Ancient Monuments Protection Act,' provision was made for the guardianship of Ancient Monuments, and a salary was assigned to an inspector who should take charge of such monuments.

It was clearly intended that other monuments of national interest should be acquired under that Act and the amending Act of 1900, and in the judgment of your memorialists it was the intention of Parliament that the duties of the inspector should include, not only the care of the scheduled monuments, but that his experience and advice should be available for such owners of similar monuments as might be desirous of vesting their possessions in the hands of public bodies.

It furthermore appears essential that such an inspector should be a man of independent position, able to give time to the duties of his office, and occupying such a status in the archæological world as to inspire the public with confidence.

We beg to observe that the Government, on taking over a number of these monuments, virtually guaranteed that they should be placed under the care of such an inspector. Since the death of General Pitt-Rivers the office of inspector has been vacant, although the salary attached to the post is annually voted by Parliament. The terms of the Act are clear and explicit, directing not merely that an inspector shall be appointed, but actually contemplating

the appointment of more than one official. We beg to observe that no option is reserved to the Government, and to remind you of the strongly expressed opinion of Archæological and kindred Societies, that the need of an inspector is urgent in order to check those injuries to ancient monuments which are of constant occurrence.

Your memorialists therefore pray the Government will proceed to make an appointment under the Act by selecting some archæologist of acknowledged experience and distinction.

It is understood that, whilst no immediate action will be taken by His Majesty's Government, the matter is receiving careful consideration by the Prime Minister, with the object of placing all ancient monuments in the United Kingdom under adequate protection and more effective supervision.

VII. The Council submit the following report by the Revision of Rules Committee and recommend for adoption the accompanying DRAFT RULES OF THE ASSOCIATION :—

The Committee, appointed by the Council on 1st June last under terms of reference given in the Minutes of the Council held on that date, made certain recommendations which were adopted by the Council and included in their Annual Report to the General Committee at the Meeting of the Association held in York. These recommendations were adopted by the General Committee.

The Committee have now completed their labours. They have revised, co-ordinated, and re-drafted the existing Rules of the Association, and have added others which comprise and contain the precedents and practice of the Association, including the duties performed by its principal office-bearers.

VIII. The Council have approved of the following STANDING ORDERS and recommend these for adoption :—

1. Papers ordered by the General Committee to be printed *in extenso* shall not be included in the Annual Report, if such papers are published elsewhere before the issue of the Report.

2. As a general rule, not more than 100 copies of each Presidential (Sectional) Address and not more than 100 copies of each Report of a Research Committee shall be printed for distribution at the Annual Meeting. In the event of a Recorder requesting any number of additional copies up to 200 for the use of his Section, such request shall be referred to the decision of the General Officers. Requests for more than 200 extra reprints shall be brought before the Council.

3. The President of a Section shall receive 100 free copies of his Presidential Address, and be entitled to obtain additional copies at the cost price of reproduction.

4. Authors of Reports and of Papers printed *in extenso* shall be entitled to receive twenty-five free copies, and to obtain additional copies at the cost price of reproduction.

5. The total annual expenditure, including printing and the issue of programmes and circulars, to be defrayed by the Association, shall not exceed £5 for any one Section. Recorders' expenses shall be limited to telegrams and postages incurred on account of Sectional work. Exceptional demands must be referred to the Council.

IX. The Council have received reports from the General Treasurer during the past year. His ACCOUNTS from July 1, 1906, to June 30, 1907, have been audited, and are presented to the General Committee.

The Council have authorised the transfer to Capital Account of a

sum not exceeding £1,500, to be invested in the names of the Trustees of the Association.

X. In accordance with the Regulations, the retiring MEMBERS OF THE COUNCIL are: *by seniority*—Professor F. Gotch, Professor W. H. Perkin, and Professor A. C. Seward; *by least attendance*—Sir George Goldie and Dr. W. N. Shaw.

The Council recommend the re-election of the other ordinary Members, with the addition of those whose names are distinguished by an asterisk in the following list, leaving two vacancies to be filled up by the General Committee:—

Abney, Sir W., K.C.B., F.R.S.
Bourne, Professor G. C., D.Sc.
Bowley, A. L., M.A.
Boys, C. Vernon, F.R.S.
Brabrook, Sir Edward, C.B.
Brown, Dr. Horace T., F.R.S.
Cunningham, Professor D. J., F.R.S.
*Dunstan, Professor W., F.R.S.
Dyson, Professor F. W., F.R.S.
*Forsyth, Professor A. R., F.R.S.
Glazebrook, Dr. R. T., F.R.S.
Haddon, Dr. A. C., F.R.S.
Hartland, E. Sidney, F.S.A.
Hawksley, C., M.Inst.C.E.
Langley, Professor J. N., F.R.S.
McKendrick, Professor J. G., F.R.S.
Mitchell, Dr. P. Chalmers, F.R.S.
Poulton, Professor E. B., F.R.S.
*Prain, Lieut.-Col. D., C.I.E., F.R.S.
*Sherrington, Professor C. S., F.R.S.
Shipley, A. E., F.R.S.
Watts, Professor W. W., F.R.S.
Woodward, Dr. A. Smith, F.R.S.

XI. The following have been admitted as Members of the GENERAL COMMITTEE:—

Professor Alexander Fraser.
Professor R. A. Gregory.
Mr. Robert Hammond.
Mr. W. Jerome Harrison.
Dr. Frederick H. Hatch.
Mr. H. Forbes Julian.
Dr. Hugh Marshall.
Dr. J. H. Vincent.
Mr. R. Bruce Young.

XII. In regard to the proposal made at York that, at future Annual Meetings, the General Committee shall hold its first sitting on Thursday at 4.30 P.M., the Council recommend that no change be made.

XIII. The Council have added the following to the Institutions entitled to receive, by exchange of publications or otherwise, the ANNUAL REPORTS of the Association: New Zealand Institute; Marine Biological Laboratory, Woods Holl, Mass., U.S.A.; Kew Gardens; Kimberley Public Library; University of Manitoba.

Approved and adopted by
the General Committee:
Leicester, July 31, 1907.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1906-1907. RECEIPTS.

	£	s.	d.
Balance brought forward	1940	14	10
Life Compositions (including Transfers)	257	0	0
New Annual Members' Subscriptions	204	0	0
Annual Subscriptions	686	0	0
Sale of Associates' Tickets	814	0	0
Sale of Ladies' Tickets	350	0	0
Sale of Publications	579	3	10
Dividend on Consols	154	8	4
Dividend on India 3 per Cents.	102	12	0
Interest on Deposit and Current Account	69	8	11
Income Tax returned	37	8	10
Unexpended balance of Grant to Committee on the Colour Physiology of the Higher Crustacea returned	9	6	9
	£5204	3	6

Investments.

	£	s.	d.
$2\frac{1}{2}$ per Cent. Consolidated Stock	6501	10	5
India 3 per Cent. Stock	3600	0	0
	£10,101	10	5
Sir Frederick Bramwell's Gift, $2\frac{1}{2}$ per Cent. Self-cumulating Consolidated Stock	63	8	10
	£10,164	19	3

JOHN PERRY, *General Treasurer.*

from July 1, 1906, to June 29, 1907. *Cr.*

1906-1907. PAYMENTS.

	£	s.	d.	£	s.	d.
Rent and Office Expenses				103	9	4
Salaries, &c.				773	11	10
Printing, Binding, &c.				1001	10	4
Expenses of York Meeting				155	0	8
Donation transferred to South African Fund				50	0	0
Payment of Grants made at York:						
Electrical Standards	50	0	0			
Seismological Observations	40	0	0			
Magnetic Observations at Falmouth	40	0	0			
Magnetic Survey of South Africa	25	7	6			
Wave-length Tables of Spectra	10	0	0			
Study of Hydro-Aromatic Substances	30	0	0			
Dynamic Isomerism	30	0	0			
Life Zones in British Carboniferous Rocks	10	0	0			
Erratic Blocks	10	0	0			
Fauna and Flora of British Trias	10	0	0			
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0			
Correlation and Age of South African Strata, &c.	10	0	0			
Table at the Zoological Station, Naples	100	0	0			
Index Animalium	75	0	0			
Development of the Sexual Cells	1	11	8			
Oscillations of the Land Level in the Mediterranean Basin	50	0	0			
Gold Coinage in Circulation in the United Kingdom	8	19	7			
Anthropometric Investigations in the British Isles	10	0	0			
Metabolism of Individual Tissues	45	0	0			
The Ductless Glands	25	0	0			
Effect of Climate upon Health and Disease	55	0	0			
Physiology of Heredity	30	0	0			
Research of South African Cycads	35	0	0			
Botanical Photographs	5	0	0			
Structure of Fossil Plants	5	0	0			
Marsh Vegetation	15	0	0			
Corresponding Societies Committee	16	14	1			
				757	12	10
				£2841	5	0
Balance at York Bank				5	10	0
Balance at Bank of England (Western Branch)	£2388	1	11			
Less Cheques not presented	41	11	8			
				2346	10	3
Cash in hand				10	18	3
				£5204	3	6

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balances at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees.

Approved—
HERBERT MCLEOD, EDWARD BRABROOK, } *Auditors.*

W. B. KEEN, *Chartered Accountant*,
3 Church Court, Old Jewry, E.C.
July 24, 1907.

General Meetings at Leicester.

On Wednesday, July 31, at 8.30 P.M., in the Opera House, Sir E. Ray Lankester, K.C.B., F.R.S., resigned the office of President to Sir David Gill, K.C.B., F.R.S., who took the Chair and delivered an Address, for which see p. 3.

On Thursday, August 1, at 8 P.M., a Fête was given in the Abbey Park by the Mayor of Leicester.

On Friday, August 2, at 8.30 P.M., in the Opera House, Mr. W. Duddell, F.R.S., delivered a Discourse on 'The Arc and the Spark in Radio-telegraphy.'

On Monday, August 5, at 8.30 P.M., in the Temperance Hall, Dr. F. A. Dixey delivered a Discourse on 'Recent Developments in the Theory of Mimicry.'

On Tuesday, August 6, at 8 P.M., a Conversazione was held in the Museum Buildings.

On Wednesday, August 7, at 2.30 P.M., the concluding General Meeting was held in the Municipal Buildings, when the following Resolutions were adopted :—

1. That a cordial vote of thanks be given to the Mayor and Corporation of Leicester for the reception which they have accorded to the British Association, and for the facilities placed at the disposal of the Officers of the Association.

2. That a cordial vote of thanks be given (i) to the Local Executive Officers and Committees for the admirable arrangements made for the meetings; (ii) to the Leicester Literary and Philosophical Society; (iii) to the public institutions which have granted the use of their buildings for sectional proceedings; and (iv) to the schools and works thrown open to the inspection of the members.

3. That the grateful thanks of the Association be given to the citizens of Leicester for the generous hospitality shown to its members on the occasion of this meeting.

4. Vote of thanks to the President for his conduct in the Chair.

The meeting was then adjourned to Dublin, September 2, 1908.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE LEICESTER MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Prof. A. E. H. Love, F.R.S. *Vice-Presidents.*—Principal E. H. Griffiths, F.R.S.; the Earl of Berkeley, F.G.S. *Secretaries.*—Prof. A. W. Porter, B.Sc. (*Recorder*); Dr. L. N. G. Filon; Dr. J. A. Harker; A. R. Hinks, M.A.; E. E. Brooks, B.Sc.

SECTION B.—CHEMISTRY.

President.—Prof. A. Smithells, F.R.S. *Vice-Presidents.*—Prof. Wyndham Dunstan, F.R.S.; Prof. W. J. Pope, F.R.S.; Sir William Crookes, F.R.S.; Sir Henry E. Roscoe, F.R.S. *Secretaries.*—Prof. A. W. Crossley, F.R.S. (*Recorder*); Dr. E. F. Armstrong; Dr. F. M. Perkin; J. H. Hawthorn, M.A.

SECTION C.—GEOLOGY.

President.—Prof. J. W. Gregory, F.R.S. *Vice-Presidents.*—Prof. Frech; Prof. J. P. Iddings; G. W. Lamplugh, F.R.S.; Prof. C. Lapworth, F.R.S.; C. Fox Strangways; Prof. W. W. Watts, F.R.S. *Secretaries.* — J. Lomas, F.G.S. (*Recorder*); Rev. W. Lower Carter, M.A.; Prof. Theodore Groom, D.Sc.; F. W. Bennett, M.D.

SECTION D.—ZOOLOGY.

President.—William E. Hoyle, M.A., D.Sc. *Vice-Presidents.*—J. J. Lister, F.R.S.; Prof. G. C. Bourne, D.Sc.; Prof. Marcus M. Hartog, D.Sc.; Prof. M. Simroth. *Secretaries.*—H. W. Marett Tims, M.D. (*Recorder*); J. H. Ashworth, D.Sc.; L. Doncaster, M.A.; E. E. Lowe.

SECTION E.—GEOGRAPHY.

President.—George G. Chisholm, M.A., B.Sc. *Vice-Presidents.*—J. Bolton; Major C. F. Close, R.E., C.M.G.; Col. Sir D. A. Johnston, K.C.M.G.; H. R. Mill, LL.D. *Secretaries.*—E. Heawood, M.A. (*Recorder*); E. A. Reeves; O. J. R. Howarth, M.A.; Theodore Walker.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Prof. W. J. Ashley, M.A. *Vice-Presidents.*—Prof. F. Y. Edgworth, D.C.L.; Prof. A. W. Flux; Prof. E. C. K. Gonner, M.A. *Secretaries.*—Prof. S. J. Chapman, M.A. (*Recorder*); H. O. Meredith, M.A.; D. H. Macgregor, M.A.; Thomas Smithies Taylor.

SECTION G.—ENGINEERING.

President.—Prof. Silvanus P. Thompson, F.R.S. *Vice-Presidents.*—Dugald Clerk; Alfred Colson; Prof. Hele-Shaw, F.R.S; Col. H. C. L. Holden, R.A., F.R.S. *Secretaries.*—W. A. Price, M.A. (*Recorder*); H. E. Wimperis, B.A.; Prof. E. G. Coker, D.Sc.; Alex. C. Harris, M A.

SECTION H.—ANTHROPOLOGY.

President—D. G. Hogarth, M.A. *Vice-Presidents.*—E. Sidney Hartland; Prof. W. Ridgeway, M.A.; Prof. E. Naville. *Secretaries.*—E. N. Fallaize, B.A. (*Recorder*); H. S. Kingsford, M.A.; F. C. Shrubsall, M.A., M.D.; Charles J. Billson, M.A.

SECTION I.—PHYSIOLOGY.

President.—Dr. A. D. Waller, F.R.S. *Vice-Presidents.*—Prof. Francis Gotch, F.R.S.; Dr. C. J. Bond; Prof. Schäfer, F.R.S.; Dr. Gaskell, F.R.S.; Prof. Sherrington, F.R.S. *Secretaries.*—J. Barcroft, M.A (*Recorder*); Dr. N. H. Alcock; Prof. J. S. Macdonald, B.A.; Allan Warner, M.D.

SECTION K.—BOTANY.

President.—Prof. J. B. Farmer, F.R.S. *Vice-Presidents.*—Dr. J. P. Lotsy; Prof. F. W. Oliver, F.R.S.; Dr. D. H. Scott, F.R.S. *Secretaries.*—Prof. A. G. Tansley, M.A. (*Recorder*); R. P. Gregory, M.A.; Prof. R. H. Yapp, M.A.; William Bell.

SECTION L.—EDUCATIONAL SCIENCE.

President.—Sir Philip Magnus, M.P. *Vice-Presidents.*—W. M. Heller; Dr. G. Kerschensteiner; Baron Kikuchi; Prof. M. Sadler, LL.D. *Secretaries*—Prof. R. A. Gregory (*Recorder*); W. D. Eggar; Hugh Richardson; J. Saville Laver.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

Chairman.—H. J. Mackinder, M.A. *Vice-Chairman.*—Rev. J. O. Bevan, M.A. *Secretary.*—F. W. Rudler, I.S O.

COMMITTEE OF RECOMMENDATIONS.

The President and Vice-Presidents of the Association; the General Secretaries; the General Treasurer; the Trustees; the Presidents of the Association in former years; Prof. Love; Principal Griffiths; Prof. Smithells; Prof. Crossley; Prof. J. W. Gregory; J. Lomas; Dr. W E. Hoyle; Dr. Marett Tims; George G. Chisholm; E. Heawood; Prof. Ashley; Prof. Chapman; Prof. Silvanus P. Thompson; W. A. Price; D. G. Hogarth; Sir Edward Brabrook; Dr. Waller; Prof. Schäfer; Prof. Farmer; Prof. Tansley; Sir Philip Magnus; Prof. R. A. Gregory; Rev. J. O. Bevan; and F. W. Rudler.

Research Committees appointed by the General Committee at the Leicester Meeting: August 1907.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
Section A.—MATHEMATICS AND PHYSICS.		£ s. d.
Seismological Observations.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Dr. J. Milne. Lord Kelvin, Dr. T. G. Bonney, Mr. C. V. Boys, Sir George Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Mr. M. H. Gray, Dr. R. T. Glazebrook, Professors J. W. Judd, C. G. Knott, and R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, and Mr. Nelson Richardson.	40 0 0
The further Tabulation of Bessel Functions.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Dr. L. N. G. Filon. Professor Alfred Lodge.	15 0 0
To co-operate with the Royal Meteorological Society in the Investigation of the Upper Atmosphere by means of Kites.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. W. H. Dines. Mr. D. Archibald, Mr. C. Vernon Boys, Dr. R. T. Glazebrook, Dr. H. R. Mill, Dr. A. Schuster, and Dr. W. Watson.	25 0 0
To co-operate with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Sir John Murray, Professor F. W. Dyson, and Mr. Omond.	25 0 0
To carry out a further portion of the Geodetic Arc of Meridian North of Lake Tanganyika.	*Chairman.*—Sir George Darwin. *Secretary.*—Sir David Gill. Major Close and Sir George Goldie.	200 0 0
Section B.—CHEMISTRY.		
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Sir Norman Lockyer, Professors Sir J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, Sir W. de W. Abney, and Dr. W. E. Adeney.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Study of Hydro-aromatic Substances.	*Chairman.*—Professor E. Divers. *Secretary.*—Professor A. W. Crossley. Professor W. H. Perkin, Dr. M. O. Forster, and Dr. Le Sueur.	30 0 0
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, Dr. A. Lapworth, and Dr. M. O. Forster.	40 0 0
The Transformation of Aromatic Nitramines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Dr. S. Ruhemann, Dr. A. Lapworth, and Dr. J. T. Hewitt.	30 0 0
SECTION C.—GEOLOGY.		
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Professor P. F. Kendall. *Secretary.*—Dr. A. R. Dwerryhouse. Dr. T. G. Bonney, Mr. F. M. Burton, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. J. Lomas, Professor W. J. Sollas, and Messrs. J. W. Stather, R. H. Tiddeman, and W. T. Tucker.	17 16 6
To report upon the Fauna and Flora of the Trias of the British Isles.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. J. Lomas. Mr. H. C. Beasley, Professor P. F. Kendall, Mr. E. T. Newton, Professor A. C. Seward, Mr. W. A. E. Ussher, Professor W. W. Watts, and Dr. A. Smith Woodward.	10 0 0
To investigate the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.	*Chairman.*—Mr. G. W. Lamplugh. *Secretary.*—Mr. J. W. Stather. Dr. Tempest Anderson, Professor J. W. Carr, Rev. W. Lower Carter, Dr. A. R. Dwerryhouse, Mr. F. W. Harmer, Mr. J. H. Howarth, Rev. W. Johnson, Professor P. F. Kendall, and Messrs. G. W. B. Macturk, E. T. Newton, H. M. Platnauer, Clement Reid, and T. Sheppard.	11 12 9
To enable Mr. E. Greenly to complete his Researches on the Composition and Origin of the Crystalline Rocks of Anglesey.	*Chairman.*—Mr. A. Harker. *Secretary.*—Mr. E. Greenly. Mr. J. Lomas, Dr. C. A. Matley, and Professor K. J. P. Orton.	2 17 2
To enable Dr. A. Vaughan to continue his Researches on the Faunal Succession in the Carboniferous Limestone in the British Isles.	*Chairman.*—Professor J. W. Gregory. *Secretary.*—Dr. A. Vaughan. Dr. Wheelton Hind and Professor W. W. Watts.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To investigate the pre-Devonian Rocks of the Mendips and the Bristol Area.	*Chairman.*—Mr. H. B. Woodward. *Secretary.*—Professor S. H. Reynolds. Dr. C. Lloyd Morgan and Rev. H. H. Winwood.	10 0 0
To record and determine the Exact Significance of Local Terms applied in the British Isles to Topographical and Geological Objects.	*Chairman.* — Mr. Douglas W. Freshfield. *Secretary.*—Mr. W. G. Fearnsides. Lord Avebury, Mr. C. T. Clough, Professor E. J. Garwood, Mr. E. Heawood, Dr. A. J. Herbertson, Col. D. A. Johnston, Mr. O. T. Jones, Dr. J. S. Keltie, Mr. G. W. Lamplugh, Mr. H. J. Mackinder, Dr. J. E. Marr, Dr. H. R. Mill, Mr. H. Yule Oldham, Dr. B. N. Peach, Professor W. W. Watts, and Mr. H. B. Woodward.	10 0 0
To excavate Critical Sections in the Palæozoic Rocks of Wales and the West of England.	*Chairman.*—Professor C. Lapworth. *Secretary.*—Mr. W. G. Fearnsides. Mr. J. Lomas, Dr. J. E. Marr, Professor W. W. Watts, and Mr. G. W. Williams.	15 0 0
To investigate the Microscopical and Chemical Composition of Charnwood Rocks.	*Chairman.* — Professor W. W. Watts. *Secretary.*—Dr. T. T. Groom. Dr. F. P. Bennett, Mr. C. Fox-Strangways, and Dr. Stracey.	10 0 0

Section D.—ZOOLOGY.

To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Rev. T. R. R. Stebbing. Sir E. Ray Lankester, Professor A. Sedgwick, Professor W. C. McIntosh, and Mr. G. P. Bidder.	100 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Dr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Dr. W. E. Hoyle, the Hon. Walter Rothschild, and Lord Walsingham.	75 0 0
To enable Mr. Laurie to conduct Experiments in Inheritance.	*Chairman.* — Professor W. A. Herdman. *Secretary.*—Mr. Douglas Laurie. Mr. R. C. Punnett and Dr. H. W. Marett Tims.	10 0 0
To assist Mr. G. W. Smith to proceed to Tasmania to study the Anatomy and Development of *Anaspides*, and to investigate the Fauna of the Lakes of Central Tasmania.	*Chairman.* — Professor G. C. Bourne. *Secretary.*—Mr. J. J. Lister. Sir E. Ray Lankester.	40 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
Section E.—GEOGRAPHY.		£ s. d.
To carry on an Expedition to investigate the Indian Ocean between India and South Africa in view of a possible land connection, to examine the deep submerged banks, the Nazareth and Saya de Malha, and also the distribution of Marine Animals.	*Chairman.*—Sir John Murray. *Secretary.*—Mr. J. Stanley Gardiner. Captain E. W. Creak, Professors W. A. Herdman, S. J. Hickson, and J. W. Judd, Mr. J. J. Lister, Dr. H. R. Mill, and Dr. David Sharp.	50 0 0
The Quantity and Composition of Rainfall, and of Lake and River Discharge.	*Chairman.*—Sir John Murray. *Secretaries.*—Professor A. B. Macallum and Dr. A. J. Herbertson. Professor W. M. Davis, Professor P. F. Frankland, Mr. A. D. Hall, Mr. N. F. Mackenzie, Mr. E. H. V. Melville, Dr. H. R. Mill, Professor A. Penck, Mr. A. Strahan, and Mr. W. Whitaker.	5 0 0
The Exploration of Prince Charles Foreland, Spitsbergen.	*Chairman.*—Mr. G. G. Chisholm. *Secretary.*—Mr. W. S. Bruce. Major W. L. Forbes.	30 0 0
Section F.—ECONOMIC SCIENCE AND STATISTICS.		
The Amount of Gold Coinage in Circulation in the United Kingdom.	*Chairman.*—Mr. R. H. Inglis Palgrave. *Secretary.*—Mr. H. Stanley Jevons. Messrs. A. L. Bowley and D. H. Macgregor.	6 0 0
Section G.—ENGINEERING.		
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Lord Rayleigh. *Secretary.*—Dr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and G. Carey Foster, Sir Oliver Lodge, Dr. A. Muirhead, Sir W. H. Preece, Professor A. Schuster, Dr. J. A. Fleming, Professor J. J. Thomson, Dr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Principal E. H. Griffiths, Sir A. W. Rücker, Professor H. L. Callendar, and Messrs. G. Matthey, A. P. Trotter, T. Mather, and F. E. Smith.	50 10 8
Section H.—ANTHROPOLOGY.		
To investigate the Lake Village at Glastonbury, and to report on the best method of publishing the result.	*Chairman.*—Dr. R. Munro. *Secretary.*—Professor W. Boyd Dawkins. Sir John Evans and Messrs. Arthur J. Evans, C. H. Read, H. Balfour, and A. Bulleid.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Professor R. C. Bosanquet. Sir Edward Brabrook, Dr. T. Ashby, Mr. D. G. Hogarth, and Professor W. Ridgeway.	15 0 0
To organise Anthropometric Investigation in the British Isles.	*Chairman.*—Professor D. J. Cunningham. *Secretary.*—Mr. J. Gray. Dr. A. C. Haddon, Dr. C. S. Myers, Professors J. L. Myres and A. F. Dixon, Mr. E. N. Fallaize, Sir Edward Brabrook, Mr. G. L. Gomme, Dr. F. C. Shrubsall, Professor G. D. Thane, Dr. W. McDougall, and Professor M. E. Sadler.	13 8 8
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. Balfour. Lord Avebury, Sir John Evans, Dr. J. G. Garson, Dr. A. J. Evans, Dr. R. Munro, Professor Boyd Dawkins, and Mr. A. L. Lewis.	53 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. S. Kingsford. Dr. T. Ashby, Dr. G. A. Auden, Mr. H. Balfour, Mr. E. N. Fallaize, Dr. A. C. Haddon, Mr. E. S. Hartland, Mr. E. Heawood, Professor J. L. Myres, and Professor Flinders Petrie.	3 3 6
To prepare a New Edition of Notes and Queries in Anthropology.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Professor J. L. Myres. Professor D. J. Cunningham, Mr. E. N. Fallaize, Dr. A. C. Haddon, Mr. T. A. Joyce, Dr. C. S. Myers, and Dr. W. H. R. Rivers.	40 0 0

Section I.—PHYSIOLOGY.

To enable Professor Starling, Professor Brodie, Dr. Hopkins, Mr. Fletcher, Mr. Barcroft, and others to determine the 'Metabolic Balance-sheet' of the Individual Tissues.	*Chairman.*—Professor Gotch. *Secretary.*—Mr. J. Barcroft. Professor T. G. Brodie and Professor Starling.	40 0 0
The Ductless Glands.	*Chairman.*—Professor Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, and Mrs. W. H. Thompson.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Effect of Climate upon Health and Disease.	*Chairman.*—Sir T. Lauder Brunton. *Secretaries.*—Mr. J. Barcroft and Lieut.-Col. Simpson. Colonel D. Bruce, Dr. F. Campbell, Sir Kendal Franks, Professor J. G. McKendrick, Sir A. Mitchell, Dr. W. C. F. Murray, Dr. Porter, Dr. J. L. Todd, Professor Sims Woodhead, Dr. A. J. Wright, and the Heads of the Tropical Schools of Liverpool, London, and Edinburgh.	35 0 0
•Body Metabolism in Cancer.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Dr. S. M. Copeman.	30 0 0
The Electrical Phenomena and Metabolism of Arum Spadices.	*Chairman.*—Professor A. D. Waller. *Secretary.*—Miss Sandars. Professor Gotch and Professor Farmer.	10 0 0

Section K.—BOTANY.

The Structure of Fossil Plants.	*Chairman.*—Dr. D. H. Scott. *Secretary.*—Professor F. W. Oliver. Mr. E. Newell Arber and Professors A. C. Seward and F. E. Weiss.	15 0 0
Studies on Marsh Vegetation.	*Chairman.*—Dr. F. F. Blackman. *Secretary.* — Professor A. C. Seward. Messrs. A. W. Hill and A. G. Tansley.	15 0 0
The Succession of Plant Remains in the Peat Deposits of Teesdale and Stainmoor (Cumberland and Westmorland) and the Western portion of Iceland.	*Chairman.*—Professor J. B. Farmer. *Secretary.*—Professor R. J. Harvey Gibson. Dr. J. Horne and Dr. J. E. Marr.	45 0 0

Section L.—EDUCATIONAL SCIENCE.

To report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Mr. W. M. Heller. Sir W. de W. Abney, Mr. R. H. Adie, Professor H. E. Armstrong, Miss L. J. Clarke, Miss A. J. Cooper, Mr. George Fletcher, Professor R. A. Gregory, Principal Griffiths, Mr. A. D. Hall, Dr. A. J. Herbertson, Dr. C. W. Kimmins, Professor L. C. Miall, Professor J. Perry, Mrs. W. N. Shaw, Professor A. Smithells, Dr. Lloyd Snape, Sir H. R. Reichel, Mr. H. Richardson, and Professor W. W. Watts.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants.
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. F. W. Rudler. Rev. J. O. Bevan, Sir Edward Brabrook, Dr. H. T. Brown, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. R. Stebbing, Professor W. W. Watts, and the President and General Officers of the Association.	£ s. d. 25 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
To co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Dr. R. T. Glazebrook. Professor W. G. Adams, Captain Creak, Mr. W. L. Fox, Professor A. Schuster, Sir A. W. Rücker, and Dr. Charles Chree.
The Consideration of the Teaching of Elementary Mechanics, and the Improvement which might be effected in such Teaching.	*Chairman.*—Professor Horace Lamb. *Secretary.*—Professor J. Perry. Mr. C. Vernon Boys, Professors Chrystal, Ewing, G. A. Gibson, and Greenhill, Principal Griffiths, Professor Henrici, Dr. E. W. Hobson, Mr. C. S. Jackson, Sir Oliver Lodge, Professors Love, Minchin, Schuster, and A. M. Worthington, and Mr. A. W. Siddons.
To continue the Magnetic Survey of South Africa commenced by Professors Beattie and Morrison.	*Chairman.*—Sir David Gill. *Secretary.*—Professor J. C. Beattie. Mr. S. S. Hough, Professor Morrison, and Professor A. Schuster.
SECTION B.—CHEMISTRY.	
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Professors W. P. Wynne and W. J. Pope.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
SECTION C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Dr. T. Anderson, Mr. G. Bingley, Dr. T. G. Bonney, Mr. H. Coates, Mr. C. V. Crook, Professor E. J. Garwood, Messrs. W. Gray, W. J. Harrison, R. Kidston, A. S. Reid, Professor S. H. Reynolds, and Messrs. J. J. H. Teall, R. Welch, and H. B. Woodward.
To investigate and report on the Correlation and Age of South African Strata and on the question of a Uniform Stratigraphical Nomenclature.	*Chairman.*—Professor J. W. Gregory. *Secretary.*—Professor A. Young. Mr. W. Anderson, Professor R. Broom, Dr. G. S. Corstorphine, Mr. Walcot Gibson, Dr. F. H. Hatch, Mr. T. H. Holland, Mr. H. Kynaston, Mr. F. P. Mennell, Dr. Molengraaff, Mr. A. J. C. Molyneux, Mr. A. W. Rogers, Mr. E. H. L. Schwarz, and Professor R. B. Young.
To determine the precise significance of Topographical and Geological Terms used locally in South Africa.	*Chairman.*—Mr. G. W. Lamplugh. *Secretary.*—Dr. F. H. Hatch. Dr. G. Corstorphine and Messrs. A. Du Toit, A. P. Hall, G. Kynaston, F. P. Mennell, and A. W. Rogers.
SECTION D.—ZOOLOGY.	
To continue the Investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Mr. F. Du Cane Godman. *Secretary.*—Dr. David Sharp. Professor S. J. Hickson, Dr. P. L. Sclater, and Mr. Edgar A. Smith.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Sir E. Ray Lankester. *Secretary.*—Professor S. J. Hickson. Professors G. C. Bourne, T. W. Bridge, J. Cossar Ewart, M. Hartog, W. A. Herdman, and J. Graham Kerr, Mr. O. H. Latter, Professor Minchin, Dr. P. C. Mitchell, Professors C. Lloyd Morgan, E. B. Poulton, and A. Sedgwick, Mr. A. E. Shipley, and Rev. T. R. R. Stebbing.
To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Mr. A. Sedgwick, and Professor Sydney H. Vines.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
To enable Dr. J. W. Jenkinson to continue his Researches on the Influence of Salt and other Solutions on the Development of the Frog.	*Chairman.*—Professor G. C. Bourne. *Secretary.*—Dr. J. W. Jenkinson. Professor S. J. Hickson.

Section E.—GEOGRAPHY.

The continued Investigation of the Oscillations of the Level of the Land in the Mediterranean Basin.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Mr. R. T. Günther. Drs. T. G. Bonney, F. H. Guillemard, J. S. Keltie, and H. R. Mill.

Section G.—ENGINEERING.

The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Sir W. H. Preece. *Secretaries.*—Mr. Dugald Clerk and Professor B. Hopkinson. Professors F. Birstall, E. G. Coker, and H. B. Dixon, Dr. J. A. Harker, Professor H. S Hele-Shaw, Colonel H. C. L. Holden, and Professor A. Smithells.

Section H.—ANTHROPOLOGY.

To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Sir John Evans. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. A. J. Evans, Mr. D. G. Hogarth, Professor A. Macalister, and Professor W. Ridgeway.
To report on the best means of Registering and Classifying systematically Megalithic Remains in the British Isles.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Dr. G. A. Auden. Dr. H. A. Auden, Mr. G. L. Gomme, Professor J. L. Myres, and Mr. F. W. Rudler.
To conduct Archæological and Ethnological Investigations in Sardinia.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Dr. W. L. H. Duckworth, Professor J. L. Myres, and Dr. F. C. Shrubsall.

Section K.—BOTANY.

To carry out the scheme for the Registration of Negatives of Botanical Photographs.	*Chairman.*—Professor F. W. Oliver. *Secretary.*—Professor F. E. Weiss. Dr. W. G. Smith, Mr. A. G. Tansley, Dr. T. W. Woodhead, and Professor R. H. Yapp.

Section L.—EDUCATIONAL SCIENCE.

To consider and to advise as to the Curricula of Secondary Schools; in the first instance, the Curricula of Boys' Schools; and to consider, through a Sub Committee, the question of the Sequence of Studies in the Science Section of the Curriculum.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Mr. C. M. Stuart. Professor H. E. Armstrong, Mr. G. F. Daniell, Mr. W. D. Eggar, Professor J. J. Findlay, Dr. Gray, Professor R. A. Gregory, Principal Griffiths, Sir W. Huggins, Mr. O. H. Latter, Sir Philip Magnus, Professor H. A. Miers, Mr. T. E. Page, Professor J. Perry, Mr. Hugh Richardson, Professor M. E. Sadler, and Mr. A. E. Shipley.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary Education.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Professor H. E. Armstrong. Sir William Bousfield, Mr. S. H. Butcher, Sir Henry Craik, Principal Griffiths, Sir Horace Plunkett, and Professor M. E. Sadler.

Communications ordered to be printed in extenso.

The Applications of Grignard's Reaction. By Dr. A. McKenzie.
Iron-ore Supplies. By Professor Sjögren.

Resolutions referred to the Council for consideration, and action, if desirable.

From Section H, supported by Section L.

That, in view of the national importance of obtaining data on the question of physical deterioration, this Association urges upon the Government the pressing necessity of instituting, in connection with the medical inspection of school children, a system of periodic measurement which shall provide definite information on their physical condition and development.

From the Conference of Delegates.

That it is desirable (1) to obtain information as to the present state of things in Britain in connection with Photo-survey work; (2) to publish instructions or give advice for the execution of a Scientific Photographic Survey; (3) to endeavour to found or promote a Photo-record of the town and district in which the British Association holds its Annual Meeting.

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the Leicester Meeting, August 1907. The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.

Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	40	0	0
*Hill, Professor M. J. M.—Further Tabulation of Bessel Functions	15	0	0
*Shaw, Dr. W. N.—Investigation of the Upper Atmosphere by Means of Kites	25	0	0
*McLaren, Lord—Meteorological Observations on Ben Nevis	25	0	0
Darwin, Sir George—Geodetic Arc in Africa	200	0	0

Chemistry.

*Roscoe, Sir H. E.—Wave-length Tables of Spectra	10	0	0
*Divers, Professor E.—Study of Hydro-aromatic Substances	30	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	40	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitramines	30	0	0

Geology.

*Kendall, Professor P. F.—Erratic Blocks	17	16	6
*Herdman, Professor W. A.—Fauna and Flora of British Trias	10	0	0
*Lamplugh, G. W.—Fossiliferous Drift Deposits	11	12	9
*Harker, A.—The Crystalline Rocks of Anglesey	2	17	2
*Gregory, Professor J. W.—Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
*Woodward, H. B.—Pre-Devonian Rocks	10	0	0
*Freshfield, D. W.—Exact Significance of Local Terms	10	0	0
Lapworth, Professor C.—Palæozoic Rocks of Wales and the West of England...	15	0	0
Watts, Professor W. W.—Composition of Charnwood Rocks	10	0	0

Zoology.

*Hickson, Professor S. J.—Table at the Zoological Station at Naples	100	0	0
*Woodward, Dr. H.—Index Animalium	75	0	0
Herdman, Professor W. A.—Heredity Experiments	10	0	0
Bourne, Professor G. C.—Fauna of Lakes of Central Tasmania	40	0	0

Geography.

*Murray, Sir John—Investigations in the Indian Ocean	50	0	0
*Murray, Sir John—Rainfall and Lake and River Discharge	5	0	0
Chisholm, G. G.—Exploration in Spitsbergen	30	0	0
Carried forward	£822	6	5

* Reappointed.

	£	s.	d.
Brought forward	822	6	5
Economic Science and Statistics.			
*Palgrave, R. H. Inglis—Gold Coinage in Circulation in the United Kingdom	6	0	0
Engineering.			
*Rayleigh, Lord—Electrical Standards	50	10	8
Anthropology.			
*Munro, Dr. R.—Glastonbury Lake Village	30	0	0
*Myres, Professor J. L.—Excavations on Roman Sites in Britain	15	0	0
*Cunningham, Professor D. J.—Anthropometric Investigation	13	8	8
*Read, C. H.—Age of Stone Circles	53	0	0
*Read, C. H.—Anthropological Photographs	3	3	6
Read, C. H.—Anthropological Notes and Queries	40	0	0
Physiology.			
*Gotch, Professor F.—Metabolism of Individual Tissues	40	0	0
*Schäfer, Professor E. A.—The Ductless Glands	30	0	0
*Brunton, Sir T. Lauder—Effect of Climate upon Health and Disease	35	0	0
Sherrington, Professor C. S.—Body Metabolism in Cancer	30	0	0
Waller, Dr. A. D.—Electrical Phenomena and Metabolism of Arum Spadices	10	0	0
Botany.			
*Scott, Dr. D. H.—Structure of Fossil Plants	15	0	0
*Blackman, Dr. F. F.—Marsh Vegetation	15	0	0
Farmer, Professor J. B.—Succession of Plant Remains	45	0	0
Educational Science.			
*Magnus, Sir P.—Studies suitable for Elementary Schools	10	0	0
Corresponding Societies Committee.			
*Whitaker, W.—For Preparation of Report	25	0	0
	£1,288	9	3

* Reappointed.

Annual Meetings, 1908 *and* 1909.

The Annual Meeting of the Association in 1908 will be held at Dublin, commencing September 2; in 1909, at Winnipeg, Canada.

ADDRESS

BY

Sir DAVID GILL, K.C.B.,

LL.D., D.Sc., F.R.S., Hon. F.R.S.E.,

PRESIDENT.

To-night, for the first time in its history, the British Association meets in the ancient city of Leicester; and it now becomes my privilege to convey to you, Mr. Mayor, and to the citizens generally, an expression of our thanks for your kind invitation and for the hospitable reception which you have accorded to us.

Here in Leicester and last year in York the Association has followed its usual custom of holding its annual meeting somewhere in the United Kingdom; but in 1905 the meeting was, as you know, held in South Africa. Now, having myself only recently come from the Cape, I wish to take this opportunity of saying that this southern visit of the Association has, in my opinion, been productive of much good: wider interest in science has been created amongst colonists, juster estimates of the country and its problems have been formed on the part of the visitors, and personal friendships and interchange of ideas between thinking men in South Africa and at home have arisen which cannot fail to have a beneficial influence on the social, political, and scientific relations between these colonies and the mother country. We may confidently look for like results from the proposed visit of the Association to Canada in 1909.

One is tempted to take advantage of the wide publicity given to words from this Chair to speak at large in the cause of science, to insist upon the necessity for its wider inclusion in the education of our youth and the devotion of a larger measure of the public funds in aid of scientific research; to point to the supreme value of science as a means for the culture of those faculties which in man promote that knowledge which is power; and to show how dependent is the progress of a nation upon its scientific attainment.

But in recent years these truths have been prominently brought

before the Association from this Chair; they have been exhaustively demonstrated by Sir William Huggins from the Chair of the Royal Society, and now a special guild[1] exists for their enforcement upon the mind of the nation.

These considerations appear to warrant me in following the healthy custom of so many previous Presidents—viz., of confining their remarks mainly to those departments of science with which the labours of their lives have been chiefly associated.

The Science of Measurement.

Lord Kelvin in 1871 made a statement from the Presidential Chair of the Association at Edinburgh as follows: 'Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than the looking for something new. But nearly all the grandest discoveries of science have been the reward of accurate measurement and patient, long-continued labour in the minute sifting of numerical results.'

Besides the instances quoted by Lord Kelvin in support of that statement, we have perhaps as remarkable and typical an exemplification as any in Lord Rayleigh's long-continued work on the density of nitrogen which led him to the discovery of argon. We shall see presently that, true as Lord Kelvin's words are in regard to most fields of science, they are specially applicable as a guide in astronomy.

One of Clerk Maxwell's lectures in the Natural Philosophy Class at Marischall College, Aberdeen, when I was a student under him there, in the year 1859, ran somewhat as follows:—

> A standard, as it is at present understood in England, is not a real standard at all; it is a rod of metal with lines ruled upon it to mark the yard, and it is kept somewhere in the House of Commons. If the House of Commons catches fire there may be an end of your standard. A copy of a standard can never be a real standard, because all the work of human hands is liable to error. Besides, will your so-called standard remain of a constant length? It certainly will change by temperature, it probably will change by age (that is, by the rearrangement or settling down of its component molecules), and I am not sure if it does not change according to the azimuth in which it is used. At all events, you must see that it is a very impractical standard—impractical because, if, for example, any one of you went to Mars or Jupiter, and the people there asked you what was your standard of measure, you could not tell them, you could not reproduce it, and you would feel very foolish. Whereas, if you told any capable physicist in Mars or Jupiter that you used some natural invariable standard, such as the wave-length of the D line of sodium vapour, he would be able to reproduce your yard or your inch, provided that you could tell him how many of such wave-lengths there were in your yard or your inch, and your standard would be available anywhere in the universe where sodium is found.

That was the whimsical way in which Clerk Maxwell used to impress

[1] The British Science Guild.

great principles upon us. We all laughed before we understood; then some of us understood and remembered.

Now the scientific world has practically adopted Maxwell's form of natural standard. It is true that it names that standard the metre; but that standard is not one ten-millionth of the Earth's quadrant in length, as it was intended to be; it is merely a certain piece of metal approximately of that length.

It is true that the length of that piece of metal has been reproduced with more precision, and is known with higher accuracy in terms of many secondary standards, than is the length of any other standard in the world; but it is, after all, liable to destruction and to possible secular change of length. For these reasons it cannot be scientifically described otherwise than as a piece of metal whose length at 0° C. at the epoch A.D. 1906 is =1,553,164 times the wave-length of the red line of the spectrum of cadmium when the latter is observed in dry air at the temperature of 15° C. of the normal hydrogen-scale at a pressure of 760 mm. of mercury at 0° C.

This determination, recently made by methods based on the interference of light-waves and carried out by MM. Benoit, Perot, and Fabry at the International Bureau of Weights and Measures, constitutes a real advance in scientific metrology. The result appears to be reliable within one ten-millionth part of the metre.

The length of the metre, in terms of the wave-length of the red line in the spectrum of cadmium, had been determined in 1892 by Michelson's method, with a mean result in almost exact accordance with that just quoted for the comparisons of 1906; but this agreement (within one part in ten millions) is due in some degree to chance, as the uncertainty of the earlier determination was probably five times greater than the difference between the two independent results of 1892 and 1906.

We owe to M. Guillaume, of the same International Bureau, the discovery of the remarkable properties of the alloys of nickel and steel, and from the point of view of exact measurement the specially valuable discovery of the properties of that alloy which we now call 'invar.' He has developed methods for treatment of wires made from this alloy which render more permanent the arrangement of their constituent molecules. Thus these wires, with their attached scales, may, for considerable periods of time and under circumstances of careful treatment, be regarded as nearly invariable standards. With proper precautions, we have found at the Cape of Good Hope that these wires can be used for the measurement of base lines of the highest geodetic precision with all the accuracy attainable by the older and most costly forms of apparatus; whilst with the new apparatus a base of 20 kilometres can be measured in less time and for less cost than one of a single kilometre with the older forms of measurement.

The Great African Arc of Meridian.

In connection with the progress of geodesy, time only permits me to say a few words about the great African arc on the 30th meridian, which it is a dream of my life to see completed.

The gap in the arc between the Limpopo and the previously executed triangulation in Rhodesia, which I reported to the Association at the Johannesburg meeting in 1905, has now been filled up. My own efforts, at 6,000 miles distance, had failed to obtain the necessary funds, but at Sir George Darwin's instance contributions were obtained from this Association, from the Royal Society and others, to the extent of half the estimated cost; the remaining half was met by the British South Africa Company. But for Darwin's happy intervention, which enabled me to secure the services of Captain Gordon and his party before the Transvaal Survey Organisation was entirely broken up, this serious gap in the great work would probably have long remained; for it is one thing to add to an existing undertaking of the kind, it is quite another to create a new organisation for a limited piece of work.

Since then Colonel (now Sir William) Morris has brought to a conclusion the reductions of the geodetic survey of the Transvaal and Orange River Colony, and his report is now in my hands for publication.

Dr. Rubin, under my direction, at the cost of the British South Africa Company, has carried the arc of meridian northwards to S. latitude 9° 42′, so that we have now continuous triangulation from Cape L'Agulhas to within fifty miles of the southern end of Lake Tanganyika; that is to say, a continuous geodetic survey extending over twenty-five degrees of latitude.

It happens that, for the adjustment of the international boundary between the British Protectorate and the Congo Free State, a topographic survey is at the present moment being executed northward along the 30th meridian from the northern border of German East Africa. A proposal on the part of the Royal Society, the Royal Geographical Society, the British Association, and the Royal Astronomical Society has been made to strengthen this work by carrying a geodetic triangulation through it along the 30th meridian, and thus adding $2\frac{1}{2}$° to the African arc. These Societies together guarantee 1,000*l.* towards the cost of the work, and ask for a like sum from Government to complete the estimated cost. The topographic survey will serve as the necessary reconnaissance. The topographic work will be completed by the end of January next, and the four following months offer the best season of the year for geodetic operations in these regions.

There is a staff of skilled officers and men on the spot sufficient to complete the work within the period mentioned, and the Intercolonial Council of the Transvaal and Orange River Colony most generously offers to lend the necessary geodetic instruments. The work will have to be done sooner or later, but if another expedition has to be organised for the

purpose the work will then cost from twice to three times the present amount. One cannot therefore doubt that his Majesty's Government will take advantage of the present offer and opportunity to vote the small sum required. This done, we cannot doubt that the German Government will complete the chain along the eastern side of Lake Tanganyika, which lies entirely within their territory. Indeed, it is no secret that the Berlin Academy of Sciences has already prepared the necessary estimates with a view to recommending action on the part of its Government.

Captain Lyons, who is at the head of the survey of Egypt, assures me that preliminary operations towards carrying the arc southwards from Alexandria have been begun, and we have perfect confidence that in his energetic hands the work will be prosecuted with vigour. In any case the completion of the African arc will rest largely in his hands. That arc, if ever my dream is realised, will extend from Cape L'Agulhas to Cairo, thence round the eastern shore of the Mediterranean and the islands of Greece, and there meet the triangulation of Greece itself, the latter being already connected with Struve's great arc, which terminates at the North Cape in lat. 70° N. This will constitute an arc of 105° in length—the longest arc of meridian that is measurable on the earth's surface.

The Solar Parallax.

Much progress has been made in the exact measurement of the great fundamental unit of astronomy—the solar parallax.

Early in 1877 I ventured to predict[1] that we should not arrive at any certainty as to the true value of the solar parallax from observations of transits of Venus, but that the modern heliometer applied to the measurement of angular distances between stars and the star-like images of minor planets would yield results of far higher precision.

The results of the observations of the minor planets Iris, Victoria, and Sappho at their favourable oppositions in the years 1888 and 1889, which were made with the co-operation of the chief heliometer and meridian observatories, fully justified this prediction.[2] The Sun's distance is now almost certainly known within one-thousandth part of its amount. The same series of observations also yielded a very reliable determination of the mass of the Moon.

The more recently discovered planet Eros, which in 1900 approached the Earth within one-third of the mean distance of the Sun, afforded a most unexpected and welcome opportunity for redetermining the solar parallax—an opportunity which was largely taken advantage of by the principal observatories of the northern hemisphere. Unfortunately the high northern declination of the planet prevented its observation at the Cape and other southern observatories. So far as the results have been

[1] 'The Determination of the Solar Parallax,' *The Observatory*, vol. i. p. 280.

[2] *Annals of the Cape Observatory*, vol. vi., part 6, p. 29.

reduced and published[1] they give an almost exact accordance with the value of the solar parallax derived from the heliometer observations of the minor planets, Iris, Victoria, and Sappho in 1888 and 1889.

But in 1931 Eros will approach the Earth within one-sixth part of the Sun's mean distance, and the fault will rest with astronomers of that day if they do not succeed in determining the solar parallax within one ten-thousandth part of its amount.

To some of us who struggled so hard to arrive at a tenth part of this accuracy under the less favourable geometrical conditions that were available before the discovery of Eros, how enviable seems the opportunity!

And yet, if we come to think of it rightly, the true opportunity and the chief responsibility is ours, for *now* and not twenty years hence is the time to begin our preparation; *now* is the time to study the origin of those systematic errors which undoubtedly attach to some of our photographic processes; and then we ought to construct telescopes specially designed for the work. These telescopes should be applied to the charting of the stars near the path which Eros will describe at its opposition in 1931, and the resulting star-co-ordinates derived from the plates photographed by the different telescopes should be rigorously intercompared. Then, if all the telescopes give identical results for the star-places, we can be certain that they will record without systematic error the position of Eros. If they do not give identical results, the source of the errors must be traced.

The planet will describe such a long path in the sky during the opposition of 1931 that it is already time to begin the meridian observations which are necessary to determine the places of the stars that are to be used for determining the constants of the plates. It is desirable, therefore, that some agreement should be come to with respect to selection of these reference-stars, in order that all the principal meridian observatories in the world may take part in observing them.

I venture to suggest that a Congress of Astronomers should assemble in 1908 to consider what steps should be taken with reference to the important opposition of Eros in 1931.

The Stellar Universe.

And now to pass from consideration of the dimensions of our solar system to the study of the stars, or other suns, that surround us.

To the lay mind it is difficult to convey a due appreciation of the value and importance of star-catalogues of precision. As a rule such catalogues have nothing whatever to do with discovery in the ordinary sense of the word, for the existence of the stars which they contain is generally well known beforehand; and yet such catalogues are, in reality, by far the most valuable assets of astronomical research.

[1] *Monthly Notices R.A.S.*, Hinks, vol. lxiv. p. 725; Christie, vol. lxvii. p. 382.

If it be desired to demarcate a boundary on the Earth's surface by astronomical methods, or to fix the position of any object in the heavens, it is to the accurate star-catalogue that we must refer for the necessary data. In that case the stars may be said to resemble the trigonometrical points of a survey, and we are only concerned to know from accurate catalogues their positions in the heavens at the epoch of observation. But in another and grander sense the stars are not mere landmarks, for each has its own apparent motion in the heavens which may be due in part to the absolute motion of the star itself in space, or in part to the motion of the solar system by which our point of view of surrounding stars is changed.

If we desire to determine these motions and to ascertain something of the general conditions which produce them, if we would learn something of the dynamical conditions of the universe and something of the velocity and direction of our own solar system through space, it is to the accurate star catalogues of widely separated epochs that we must turn for a chief part of the requisite data.

The value of a star-catalogue of precision for present purposes of cosmic research varies as the square of its age and the square of its accuracy. We cannot alter the epoch of our observations, but we can increase their value fourfold by doubling their accuracy. Hence it is that many of our greater astronomers have devoted their lives chiefly to the accumulation of meridian observations of high precision, holding the view that to advance such precision is the most valuable service to science they could undertake, and comforted in their unselfish and laborious work only by the consciousness that they are preparing a solid foundation on which future astronomers may safely raise the superstructure of sound knowledge.

But since the extension of our knowledge of the system of the universe depends quite as much on past as on future research, it may be well, before determining upon a programme for the future, to consider briefly the record of meridian observation in the past for both hemispheres.

The Comparative State of Astronomy in the Northern and Southern Hemispheres.

It seems probable that the first express reference to southern constellations in known literature occurs in the Book of Job (ix. 9): 'Which maketh Arcturus, Orion, and Pleiades, and the chambers of the south.' Schiaparelli's strongly supported conjecture is that the expression 'chambers of the south,' taken with its context, signifies the brilliant stellar region from Canopus to α Centauri, which includes the Southern Cross and coincides with the most brilliant portion of the Milky Way.

About the year 750 B.C. (the probable date of the Book of Job) all these stars culminated at altitudes between 5° and 16° when viewed from

the latitude of Judæa ; but now, owing to precessional change, they can only be seen in a like striking manner from a latitude about 12° further south.

The words of Dante have unquestionably originated the wonderful net of poetic fancy that has been woven about the asterism, which we now call Crux.

> To the right hand I turned, and fixed my mind
> On the other pole attentive, where I saw
> Four stars ne'er seen before save by the ken
> Of our first parents—Heaven of their rays
> Seemed joyous. O thou northern site ! bereft
> Indeed, and widowed, since of these deprived.

All the commentators agree that Dante here referred to the stars of the Southern Cross.

Had Dante any imperfect knowledge of the existence of these stars, any tradition of their visibility from European latitudes in remote centuries, so that he might poetically term them the stars of our first parents ?

Ptolemy catalogues them as 31, 32, 33, and 34 Centauri, and they are clearly marked on the Borgian globe described by Assemanus in 1790. This globe was constructed by an Arabian in Egypt : it bears the date 622 Hegira, corresponding with A.D. 1225, and it is possible that Dante may have seen it.

Amerigo Vespucci, as he sailed in tropical seas, apparently recognised in what we now call Crux the four luminous stars of Dante ; for in 1501 he claimed to be the first European to have looked upon the stars of our first parents. His fellow-voyager, Andrea Corsali, wrote about the same time to Giuliano di Medici describing 'the marvellous cross, the most glorious of all the celestial signs.'

Thus much mysticism and romance have been woven about this constellation, with the result that exaggerated notions of its brilliancy have been formed, and to most persons its first appearance, when viewed in southern latitudes, is disappointing.

To those, however, who view it at upper culmination for the first time from a latitude a little south of the Canary Islands, and who at the same time make unconsciously a mental allowance for the absorption of light to which one is accustomed in the less clear skies of Northern Europe, the sight of the upright cross, standing as if fixed to the horizon, is a most impressive one. I at least found it so on my first voyage to the Cape of Good Hope. But how much more strongly must it have appealed to the mystic and superstitious minds of the early navigators as they entered the unexplored seas of the northern tropic ! To them it must have appeared the revered image of the Cross pointing the way on their southward course—a symbol and sign of Hope and Faith on their entry to the unknown.

The first general knowledge of the brighter stars of the southern

hemisphere we owe to Frederick de Hautman, who commanded a fleet sent by the Dutch Government in 1595 to the Far East for the purpose of exploring Japan. Hautman was wrecked and taken prisoner at Sumatra, and whilst there he studied the language of the natives and made observations of the positions and magnitudes of the fixed stars of the southern hemisphere.[1]

Our distinguished countryman Halley visited St. Helena in 1677 for the purpose of cataloguing the stars of the southern hemisphere. He selected a station now marked Halley's Mount on the Admiralty chart of the island. I have visited the site, and the foundations of the observatory still remain. Halley's observations were much hindered by cloud. On his return to England, Halley in 1679 published his 'Catalogus Stellarum Australium,' containing the magnitudes, latitudes, and longitudes of 341 stars, which, with the exception of seven, all belonged to the southern hemisphere.

But the first permanently valuable astronomical work in the southern hemisphere was done in 1751–52 by the Abbé de Lacaille. He selected the Cape of Good Hope as the scene of his labours, because it was then perhaps the only spot in the world situated in a considerable southern latitude which an unprotected astronomer could visit in safety, and where the necessary aid of trained artisans to erect his observatory could be obtained. Lacaille received a cordial welcome at the hands of the Dutch governor Tulbagh : he erected his observatory in Cape Town, made a catalogue of nearly 10,000 stars, observed the opposition of Mars, and measured a short arc of meridian all in the course of a single year. Through his labours the Cape of Good Hope became the birthplace of astronomy and geodesy in the southern hemisphere.

Bradley was laying the foundations of exact astronomy in the northern hemisphere at the time when Lacaille laboured at the Cape. But Bradley had superior instruments to those of Lacaille and much longer time at his disposal. Bradley's work is now the basis on which the fair superstructure of modern astronomy of precision rests. His labours were continued by his successors at Greenwich and by a long series of illustrious men like Piazzi, Groombridge, Bessel, Struve, and Argelander. But in the southern hemisphere the history of astronomy is a blank for seventy years from the days of Lacaille.

We owe to the establishment of the Royal Observatory at the Cape by an Order in Council of 1820 the first successful step towards the foundation of astronomy of high precision in the southern hemisphere.

Time does not permit me to trace in detail the labours of astronomers in the southern hemisphere down to the present day ; and this is the less necessary because in a recent Presidential Address to the South African Philosophical Society[2] I have given in great part that history in

[1] The resulting catalogue of 304 stars is printed as an appendix to Hautman's *Vocabulary of the Malay Language*, published at Amsterdam in 1603.

[2] *Trans. South African Phil. Soc.*, vol. xiv. part 2.

considerable detail. But I have not there made adequate reference to the labours of Dr. Gould and Dr. Thome at Cordoba. To their labours, combined with the work done under Stone at the Cape, we owe the fact that for the epoch 1875 the meridian sidereal astronomy of the southern hemisphere is nearly as well provided for as that of the northern. The point I wish to make is that the facts of exact sidereal astronomy in the southern hemisphere may be regarded as dating nearly a hundred years behind those of the northern hemisphere.

The Constitution of the Universe.

It was not until 1718, when Edmund Halley, afterwards Astronomer Royal of England, read a paper before the Royal Society,[1] entitled 'Considerations on the Change of the Latitudes of Some of the Principal Fixt Stars,' that any definite facts were known about the constitution of the universe. In that paper Halley, who had been investigating the precession of the equinoxes, says: 'But while I was upon this enquiry I was surprized to find the Latitudes of three of the principal Stars in heaven directly to contradict the supposed greater obliquity of the Ecliptick, which seems confirmed by the Latitudes of most of the rest.'

This is the first mention in history of an observed change in the relative position of the so-called fixed stars—the first recognition of what we now call 'proper motion.'

Tobias Mayer, in 1760, seems to have been the first to recognise that if our Sun, like other stars, has motion in space, that motion must produce apparent motion amongst the surrounding stars; for in a paper to the Gottingen Academy of Sciences he writes: 'If the Sun, and with it the planets and the Earth which we inhabit, tended to move directly towards some point in the heavens, all the stars scattered in that region would seem to gradually move apart from each other, whilst those in the opposite quarter would mutually approach each other. In the same manner one who walks in the forest sees the trees which are before him separate, and those that he leaves behind approach each other.' No statement of the matter could be more clear; but Mayer, with the meagre data at his disposal, came to the conclusion that 'the motions of the stars are not governed by the above or any other common law, but belong to the stars themselves.'

Sir William Herschel, in 1783, made the first attempt to apply, with any measure of success, Mayer's principle to a determination of the direction and amount of the solar motion in space.[2] He derived, as well as he could from existing data, the proper motions of fourteen stars, and arrived by estimation at the conclusion that the Sun's motion in space is nearly in the direction of the star λ Herculis, and that 80 per cent. of the apparent motions of the fourteen stars in question could be assigned to this common origin.

[1] *Phil. Trans.*, 1718, p. 738.

[2] *Ibid.*, 1783, p. 247.

This conclusion rests in reality upon a very slight basis, but the researches of subsequent astronomers show that it was an amazing accidental approach to truth—indeed, a closer approximation than Herschel's subsequent determinations of 1805 and 1806, which rested on wider and better data.[1]

Consider for a moment the conditions of the problem. If all the stars except our Sun were at rest in space, then, in accordance with Mayer's statement, just quoted, all the stars would have apparent motions on great circles of the sphere away from the apex and towards the antapex of the solar motion. That is to say, if the position of each star of which the apparent motion is known was plotted on the surface of a sphere and a line with an arrow-head drawn through each star showing the direction of its motion on the sphere, then it should be possible to find a point on the sphere such that a great circle drawn from this point through any star would coincide with the line of direction of that star's proper motion. The arrow-heads would all point to that intersection of the great circles which is the antapex of the solar motion, and the other point of intersection of the great circles would be the apex, that is to say, the direction of the Sun's motion in space.

But as the apparent stellar motions are small and only determinable with a considerable percentage of error, it would be impossible to find any point on the sphere such that every great circle passing through it and any particular star, would in every case be coincident with the observed direction of motion of that star.

Such discordances would, on our original assumption, be due to errors of observation, but in reality much larger discordances will occur, which are due to the fact that the other stars (or suns) have independent motions of their own in space. This at once creates a new difficulty, viz., that of defining an absolute locus in space. The human mind may exhaust itself in the effort, but it can never solve the problem. We can imagine, for example, the position of the Sun at any moment to be defined with reference to any number of surrounding stars, but by no effort of imagination can we devise means of defining the *absolute* position of a body in space without reference to surrounding material objects. If, therefore, the referring objects have unknown motions of their own, the rigour of the definition is lost.

What we call the observed proper motion of a star has three possible sources of origin :—

1. The *parallactic motion*, or the effect of our Sun's motion through space, whereby our point of view of surrounding celestial objects is changed.

2. The *peculiar* or particular motion of the star, *i.e.*, its own *absolute* motion in space.

3. That part of the observed or tabular motion which is due to inevitable error of observation.

[1] *Phil. Trans.*, 1805, p. 233 ; 1806, p. 205.

In all discussions of the solar motion in space, from that of Herschel down till a recent date, it has been assumed that the peculiar motions of the stars are arranged at random, and may therefore be considered zero in the mean of a considerable number of them. It is then possible to find such a value for the Precession, and such a common apex for the solar motion as shall leave the residual peculiar motions of the stars under discussion to be in the mean = zero. That is to say, we refer the motion of the Sun in space to the centre of gravity of all the stars considered in the discussion, and regard that centre of gravity as immovable in space.

In order to proceed rigorously, and especially to determine the amount as well as the direction of the Sun's motion in space, we ought to know the parallax of every star employed in the discussion, as well as its proper motion. In the absence of such data it has been usual to start from some such assumption as the following: the stars of a particular magnitude are roughly at the same distance; those of different classes of magnitude may be derived from the hypothesis that on the average they have all equal absolute luminosity.

The assumption is not a legitimate one—

1. Because of the extreme difference in the absolute luminosity of stars.

2. Because it implies that the average absolute luminosity of stars is the same in all regions of space.

The investigation has been carried out by many successive astronomers on these lines with fairly accordant results as to the position of the solar apex, but with very unsatisfactory results as to the distances of the fixed stars.[1] In order to judge how far the magnitude (or brightness) of a star is an index of its probable distance, we must have evidence from direct determinations of stellar parallax.

[1] Argelander, *Mém. présentés à l'Acad. Imp. des Sciences St. Pétersbourg*, tome iii.

Lundahl, *Astron. Nachrichten*, **398**, 209.

Argelander, *Astron. Nachrichten*, **398**, 210.

Otto Struve, *Mém. Acad. des Sciences St. Pétersbourg*, vi^e^ série, Math. et Phys., tome iii. p. 17.

Galloway, *Phil. Trans.*, 1847, p. 79.

Mädler, *Dorpat Observations*, vol. xiv., and *Ast. Nach.*, **566**, 213.

Airy, *Mem. R.A.S.*, vol. xxviii. p. 143.

Dunkin, *Mem. R.A.S.*, vol. xxxii. p. 19.

Stone, *Monthly Notices R.A.S.*, vol. xxiv. p. 36.

De Ball, *Inaugural Dissertation*, Bonn, 1877.

Rancken, *Astron. Nachrichten*, **2482**, 149.

Bischoff, *Inaugural Dissertation*, Bonn, 1884.

Ludwig Struve, *Mém. Acad. St. Pétersbourg*, vii^e^ série, tome xxxv. No. 3.

Stellar Parallax.

To extend exact measurement from our own solar system to that of other suns and other systems may be regarded as the supreme achievement of practical astronomy. So great are the difficulties of the problem, so minute the angles involved, that it is but in comparatively recent years that any approximate estimate could be formed of the true parallax of any fixed star. Bradley felt sure that if the star γ Draconis had a parallax of 1″ he would have detected it. Henderson by 'the minute sifting of the numerical results' of his own meridian observations of α Centauri, made at the Cape of Good Hope in 1832–33, first obtained certain evidence of the measurable parallax of any fixed star. He was favoured in this discovery by the fact that the object he selected happened to be, so far as we yet know, the nearest sun to our own. Shortly afterwards Struve obtained evidence of a measurable parallax for α Lyræ and Bessel for 61 Cygni. Astronomers hailed with delight this bursting of the constraints which our imperfect means imposed on research. But for the great purposes of cosmical astronomy what we are chiefly concerned to know is not what is the parallax of this or that particular star, but rather what is the average parallax of a star having a particular magnitude and proper motion. The prospect of even an ultimate approximate attainment of this knowledge seemed remote. The star α Lyræ is one of the brightest in the heavens; the star 61 Cygni one that had the largest proper motion known at the time; whilst α_2 Centauri is not only a very bright star, but it has also a large proper motion. The parallaxes of these stars must therefore in all probability be large compared with the parallax of the average star; but yet to determine them with approximate accuracy long series of observations by the greatest astronomers and with the finest instruments of the day seemed necessary.

Subsequently various astronomers investigated the parallaxes of other stars having large proper motions, but it was only in 1881, at the Cape of Good Hope, that general research on stellar parallax was instituted.[1] Subsequently at Yale and at the Cape of Good Hope the work was continued on cosmical lines with larger and improved heliometers.[2] By the introduction of the reversing prism and by other practical refinements the possibilities of systematic error were eliminated, and the accidental errors of observation reduced within very small limits.

These researches brought to light the immense diversity in the absolute luminosity and velocity of motion of different stars. Take the following by way of example:—

Our nearest neighbour amongst the stars, α_2 Centauri, has a parallax

[1] *Mem. R.A.S.*, vol. xlviii.

[2] *Annals of the Cape Observatory*, vol. viii. part 2, and *Trans. Astron. Observatory of Yale University*, vol. i.

of 0″·76, or is distant about $4\frac{1}{3}$ light-years. Its mass is independently known to be almost exactly equal to that of our Sun; and its spectrum being also identical with that of our Sun, we may reasonably assume that it appears to us of the same magnitude as would our Sun if removed to the distance of α_2 Centauri.

But the average star of the same apparent magnitude as α_2 Centauri was found to have a parallax of only 0″·10, so that either α_2 Centauri or our Sun, if removed to a distance equal to that of the average fixed star of the first magnitude would appear to us but little brighter than a star of the fifth magnitude.

Again, there is a star of only $8\frac{1}{2}$ magnitude [1] which has the remarkable annual proper motion of nearly $8\frac{3}{4}$ seconds of arc—one of those so-called runaway stars—which moves with a velocity of 80 miles per second at right angles to the line of sight (we do not know with what velocity in the line of sight). It is at about the same distance from us as Sirius, but it emits but one ten-thousandth part of the light energy of that brilliant star. Sirius itself emits about thirty times the light-energy of our Sun, but it in turn sinks into insignificance when compared with the giant Canopus, which emits at least 10,000 times the light-energy of our Sun.

Truly 'one star differs from another star in glory.' Proper motion rather than apparent brightness is the truer indication of a star's probable proximity to the Sun. Every star of considerable proper motion yet examined has proved to have a measurable parallax.

This fact at once suggests the idea, Why should not the apparent parallactic motions of the stars, as produced by the Sun's motion in space, be utilised as a means of determining stellar parallax?

Secular Parallactic Motion of Stars.

The strength of such determinations, unlike those made by the method of annual parallax, would grow with time. It is true that the process cannot be applied to the determination of the parallax of individual stars, because the peculiar motion of a particular star cannot be separated from that part of its apparent motion which is due to parallactic displacement. But what we specially want is not to ascertain the parallax of the individual star, but the mean parallax of a particular group or class of stars, and for this research the method is specially applicable, provided we may assume that the peculiar motions are distributed at random, so that they have no systematic tendency in any direction; in other words, that the centre of gravity of any extensive group of stars will remain fixed in space.

This assumption is, of course, but a working hypothesis, and one which from the paper on star-streaming communicated by Professor Kapteyn of Groningen to the Johannesburg meeting of the Association two years ago we already know to be inexact.[2] Kapteyn's results were quite recently

[1] Gould's Zones, V^h 243.

[2] *Rep. Brit. Assoc.*, 1905, p. 257.

confirmed in a remarkable way by Eddington,[1] using independent material discussed by a new and elegant method. Both results showed that, at least for extensive parts of space, there are a nearly equal number of stars moving in exactly opposite directions. The assumption, then, that the mean of the peculiar motions is zero may, at least for these parts of space, be still regarded as a good working hypothesis.

Adopting an approximate position of the apex of the solar motion, Kapteyn resolved the observed proper motions of the Bradley stars into two components, viz., one in the plane of the great circle passing through the star and the apex, the other at right angles to that plane.[2] The former component obviously includes the whole of the parallactic motion; the latter is independent of it, and is due entirely to the real motions of the stars themselves. From the former the mean parallactic motion of the group is derived, and from the combination of the two components, the relation of velocity of the Sun's motion to that of the mean velocity of the stars of the group.

As the distance of any group of stars found by the parallactic motion is expressed as a unit in terms of the Sun's yearly motion through space, the velocity of this motion is one of the fundamental quantities to be determined. If the mean parallax of any sufficiently extensive group or class of stars was known we should have at once means for a direct determination of the velocity of the Sun's motion in space; or if, on the other hand, we can by independent methods determine the Sun's velocity, then the mean parallax of any group of stars can be determined.

Determination of Stellar Motion in the Line of Sight.

Science owes to Sir William Huggins the application of Doppler's principle to the determination of the velocity of star-motion in the line of sight. The method is now so well known, and such an admirable account of its theory and practical development was given by its distinguished inventor from this Chair at the Cardiff meeting in 1891, that further mention of that part of the matter seems unnecessary.

The Velocity of the Sun's Motion in Space.

If by this method the velocities in the line of sight of a sufficient number of stars situated near the apex and antapex of the solar motion could be determined, so that in the mean it could be assumed that their peculiar motions would disappear, we have at once a direct determination of the required velocity of the Sun's motion.

The material for this determination is gradually accumulating, and indeed much of it, already accumulated, is not yet published. But even with

[1] *Monthly Notices R.A.S.*, vol. lxvii. p. 34.
[2] *Publications Astron. Laboratory Groningen*, Nos. 7 and 9.

the comparatively scant material available, it now seems almost certain that the true value of the Sun's velocity lies between 18 and 20 kilometres per second;[1] or, if we adopt the mean value, 19 kilometres per second, this would correspond almost exactly with a yearly motion of the Sun through space equal to four times the distance of the Sun from the Earth.

Thus the Sun's yearly motion being four times the Sun's distance, the parallactic motion of stars in which this motion is unforeshortened must be four times their parallax. How this number varies with the amount of foreshortening is of course readily calculated. The point is that from the mean parallactic motion of a group of stars we are now enabled to derive at once its mean parallax.

This research has been carried out by Kapteyn for stars of different magnitudes. It leads to the result that the parallax of stars differing *five* magnitudes does *not* differ in the proportion of one to ten, as would follow from the supposition of equal luminosity of stars throughout the universe, but only in the proportion of about one to five.[2]

The same method cannot be applied to groups of stars of different proper motions, and it is only by a somewhat indirect proof, and by calling in the aid of such reliable results of direct parallax determination as we possess, that the variation of parallax with proper motion could be satisfactorily dealt with.

The Mean Parallaxes of Stars of Different Magnitude and Proper Motion.

As a final result Kapteyn derived an empirical formula giving the average parallax for stars of different spectral types, and of any given magnitude and proper motion. This formula was published at Groningen in 1901.[3] Within the past few months the results of researches on stellar parallax, made under the direction of Dr. Elkin, at the Astronomical Observatory of Yale University, during the past thirteen years,[4] have been published, and they afford a most crucial and entirely independent check on the soundness of Kapteyn's conclusions.

In considering the comparison between the more or less theoretical results of Kapteyn and the practical determinations of Yale, we have to remember that Kapteyn's tables refer only to the means of groups of a large number of stars having on the average a specified magnitude and proper motion, whilst the latter are direct determinations affected by the accidental errors of the separate determinations and by such uncertainty as attaches to the unknown parallaxes of the comparison stars—parallaxes which we have supplied from Kapteyn's general tables.

The Yale results consist of the determination of the parallax of 173 stars, of which only ten had been previously known to Kapteyn and had

[1] *Kapteyn Ast. Nach.*, No. 3487, p. 108; and Campbell, *Astrophys. Journ.*, xiii. p. 80.

[2] *Astron. Nachrichten*, No. 3487, Table III.; and *Ast. Journ.*, p. 566.

[3] *Publications Astron. Laboratory Groningen*, No. 8, p. 24.

[4] *Trans. Astron. Observatory of Yale Univ.*, vol. ii., part 1.

been utilised by him. Dividing these results into groups we get the following comparison :—

Comparison Groups arranged in order of Proper Motion.

No. of Stars	Proper Motion	Magnitude	Parallax		Yale—Kapteyn
			Yale	Kapteyn	
21	0″·14	3·8	0″·028	0″·026	+0″·002
39	0·49	6·3	·042	·055	− ·013
45	0·59	6·7	·068	·060	+ ·008
46	0·77	6·5	·047	·074	− ·027
22	1·50	6·2	·118	·124	− ·006

Groups arranged in order of Magnitude.

No. of Stars	Proper Motion	Magnitude	Parallax		Yale—Kapteyn
			Yale	Kapteyn	
10	0″·61	0·8	0″·103	0″·110	−0″·007
29	·53	3·8	·076	·075	+ ·001
33	·63	5 6	·064	·070	− ·006
34	·73	6·7	·055	·070	− ·017
31	·68	7·6	·025	·061	− ·036
36	·80	8·3	·056	·062	− ·006

—	No. of Stars	Proper Motion	Magnitude	Parallax		Yale—Kapteyn
				Yale	Kapteyn	
Spectral Type I. .	13	0″·42	4·0	0″·076	0″·076	0″·000
„ „ II. .	81	0·67	5·3	0·067	0·074	−0·007

These results agree in a surprisingly satisfactory way, having regard to the comparatively small number of stars in each group and the great range of parallax which we know to exist amongst individual stars having the same magnitude and proper motion. In the mean perhaps the tabular parallaxes are in a minute degree too large, but we have unquestionable proof from this comparison that our knowledge of stellar distances now rests on a solid foundation.

The Distribution of Varieties of Luminosity of Stars.

But, besides the mean parallax of stars of a particular magnitude and proper motion, it is essential that we should know approximately what percentage of the stars of such a group have twice, three times, &c., the mean parallax of the group, and what percentage only one-half, one-third of that parallax, and so on. In principle, at least, this frequency-law may be obtained by means of the directly determined parallaxes. For the stars of which we have reliable determinations we can compare

these true parallaxes with the *mean* parallax of stars having corresponding magnitude and proper motion, and this comparison will lead to a knowledge of the frequency-law required. It is true that, owing to the scarcity of material at present available, the determination of the frequency-law is not so strong as may be desirable, but further improvement is simply a question of time and the augmentation of parallax-determination.

Adopting provisionally the frequency-law found in this way by Kapteyn,[1] we can localise all the stars in space down to about the ninth magnitude.

Take, for example, the stars of magnitude 5·5 to 6·5. There are about 4,800 of these stars in the whole sky. According to Auwers-Bradley, about $9\frac{1}{2}$ per cent. of these stars, or some 460 in all, have proper motions between $0''\cdot04$ and $0''\cdot05$. Now, according to Kapteyn's empiric formula, whose satisfactory agreement with the Yale results has just been shown, the mean parallax of such stars is almost exactly $0''\cdot01$. Further, according to his frequency-law, 29 per cent. of the stars have parallaxes between the *mean* value and double the mean value; 6 per cent. have parallaxes between twice and three times the mean value; $1\frac{1}{2}$ per cent. between three and four times the mean value. Therefore of our 460 stars 133 will have parallaxes between $0''\cdot01$ and $0''\cdot02$, twenty-eight between $0''\cdot02$ and $0''\cdot03$, seven between $0''\cdot03$ and $0''\cdot04$, and so on.

Localising in the same way the stars of the sixth magnitude having other proper motions, and then treating the stars of the first magnitude, second magnitude, third magnitude, and so on to the ninth magnitude in the same way, we finally locate all these stars in space.[2]

It is true we have not localised the individual stars, but we know approximately and within certain limits of magnitude the number of stars at each distance from the Sun.

Thus the apparent brightness and the distance being known we have the means of determining the light-energy or absolute *luminosity* of the stars, *provided it can be assumed that light does not suffer any extinction in its passage through interstellar space.*

On this assumption Kapteyn was led to the following results, viz., that within a sphere the radius of which is 560 light-years (a distance which corresponds with that of the average star of the ninth magnitude) there will be found :—

1	star	giving from	100,000	to	10,000	times	the light of	our Sun.
26	stars	„	10,000	„	1,000	„	„	„
1,300	„	„	1,000	„	100	„	„	„
22,000	„	„	100	„	10	„	„	„
140,000	„	„	10	„	1	„	„	„
430,000	„	„	1	„	0·1	„	„	„
650,000	„	„	0·1	„	0·01	„	„	„

[1] *Publications Astron. Lab. Groningen*, No. 8, p. 23.
[2] *Ibid.*, No. 11, Table II.

The Density of Stellar Distribution at Different Distances from our Sun.

Consider, lastly, the distribution of stellar density, that is, the number of stars contained in the unit of volume.

We cannot determine *absolute* star-density, because, for example, some of the stars which we know from their measured parallaxes to be comparatively near to us are in themselves so little luminous that if removed to even a few light-years greater distance they would appear fainter than the ninth magnitude, and so fall below the magnitude at which our data at present stop.

But if we assume that intrinsically faint and bright stars are distributed in the same proportion in space, it will be evident that the comparative richness of stars in any part of the system will be the same as the comparative richness of the same part of the system in stars of a particular luminosity. Therefore, as we have already found the arrangement in space of the stars of different degrees of luminosity, and consequently their number at different distances from the Sun, we must also be able to determine their relative density for these different distances.

Kapteyn finds in this way that, starting from the Sun, the star-density (*i.e.*, the number of stars per unit volume of space) is pretty constant till we reach a distance of some 200 light-years. Thence the density gradually diminishes till, at about 2,500 light-years, it is only about *one-fifth* of the density in the neighbourhood of the Sun.[1] This conclusion must, however, be regarded as uncertain until we have by independent means been enabled to estimate the absorption of light in its course through interstellar space, and obtained proof that the ratio of intrinsically faint to bright stars is constant throughout the universe.

Thus far Kapteyn's researches deal with the stellar universe as a whole; the results, therefore, represent only the *mean* conditions of the system. The further development of our knowledge demands a like study applied to the several portions of the universe separately. This will require much more extensive material than we at present possess.

As a first further approximation the investigation will have to be applied separately to the Milky Way and the parts of the sky of higher galactic latitude. The velocity and direction of the Sun's motion in space may certainly be treated as constants for many centuries to come, and these constants may be separately determined from groups of stars of various regions, various magnitudes, various proper motions, and various spectral types. If these constants as thus separately determined are different, the differences which are not attributable to errors of observation must be due to a common velocity or direction of motion of the group or class of star to which the Sun's velocity or direction is referred. Thus, for example, the Sun's velocity as determined by spectroscopic observations

[1] *Publications Astron. Lab. Groningen*, No. 11.

of motion in the line of sight, appears to be sensibly smaller than that derived from fainter stars. The explanation appears to be that certain of the brighter stars form part of a cluster or group of which the Sun is a member, and these stars tend to some extent to travel together. For these researches the existing material, especially that of the determination of velocities in the line of sight, is far too scanty.

Kapteyn has found that stars whose proper motions exceed $0''\cdot05$ are not more numerous in the Milky Way than in other parts of the sky;[1] in other words, if only the stars having proper motions of $0''\cdot05$ or upwards were mapped there would be no aggregation of stars showing the existence of a Milky Way.

The proper motions of stars of the second spectral type are, as a rule, considerably larger than those of the first type; but Kapteyn comes to the conclusion that this difference does not mean a real difference of velocity, but only that the second-type stars have a smaller luminosity, the mean difference between the two types amounting to $2\frac{1}{2}$ magnitudes.[2]

The Future Course of Research.

In the last Address delivered from this Chair on an astronomical subject, Sir William Huggins, in 1891, dealt so fully with the chemistry of the stars that it seemed fitting on the present occasion to consider more especially the problem of their motion and distribution in space, as it is in this direction that the most striking advances in our knowledge have recently been made. It is true that since 1891 great advances have also been made in our detailed knowledge of the chemistry of the Sun and stars. The methods of astro-spectrography have been greatly improved, the precision of the determination of motion in the line of sight greatly enhanced, and many discoveries made of those close double stars, ordinarily termed spectroscopic doubles, the study of which seems destined to throw illustrative light upon the probable history of the development of systems from the original nebular condition to that of more permanent systems.

But the limitations of available time prevent me from entering more fully into this tempting field, more especially as it seems desirable, in the light of what has been said, to indicate the directions in which some of the astronomical work of the future may be most properly systematised. There are two aspects from which this question may be viewed. The first is the more or less immediate extension of knowledge or discovery; the second the fulfilment of our duty, as astronomers, to future generations. These two aspects should never be entirely separated. The first, as it opens out new vistas of research and improved methods of work, must often serve as a guide to the objects of the second. But the second is to the astronomer the supreme duty, viz., to secure for future generations those data the value of which grows by time.

[1] *Verl. Kn. Akad. Amsterdam*, January 1893.
[2] *Ibid.*, April 1892.

As the result of the Congress of Astronomers held at Paris in 1887 some sixteen of the principal observatories in the world are engaged, as is well known, in the laborious task, not only of photographing the heavens, but of measuring these photographs and publishing the *relative* positions of the stars on the plates down to the eleventh magnitude. A century hence this great work will have to be repeated, and then, if we of the present day have done our duty thoroughly, our successors will have the data for an infinitely more complete and thorough discussion of the motions of the sidereal system than any that can be attempted to-day. But there is still needed the accurate meridian observation of some eight or ten stars on each photographic plate, so as to permit the conversion of the *relative* star-places on the plate into *absolute* star-places in the heavens. It is true that some of the astronomers have already made these observations for the reference stars of the zones which they have undertaken. But this seems to be hardly enough. In order to co-ordinate these zones, as well as to give an accuracy to the *absolute* positions of the reference stars corresponding with that of the *relative* positions, it is desirable that this should be done for *all* the reference stars in the sky by several observatories. The observations of well-distributed stars by Kustner at Bonn present an admirable instance of the manner in which the work should be done. Several observatories in each hemisphere should devote themselves to this work, employing the same or other equally efficient means for the elimination of sources of systematic error depending on magnitude, &c., and it is of far more importance that we should have, say, two or three observations of each star at three different observatories than two or three times as many observations of each star made at a single observatory.

The southern cannot boast of a richness of instrumental and personal equipment comparable with that of the northern hemisphere, and consequently one welcomes with enthusiasm the proposal on the part of the Carnegie Institute to establish a meridian observatory in a suitable situation in the southern hemisphere. Such an observatory, energetically worked, with due attention to all necessary precautions for the exclusion of systematic errors, would conduce more than anything else to remedy in some degree that want of balance of astronomical effort in the two hemispheres to which allusion has already been made. But in designing the programme of the work it should be borne in mind that the proper duty of the meridian instrument in the present day is no longer to determine the positions of all stars down to a given order of magnitude, but to determine the positions of stars which are geometrically best situated and of the most suitable magnitude for measurement on photographic plates, and to connect these with the fundamental stars. For this purpose the working list of such an observatory should include only the fundamental stars and the stars which have been used as reference stars for the photographic plates.

Such a task undertaken by the Carnegie Observatory, by the Cape,

and if possible by another observatory in the southern hemisphere, and by three observatories in the northern, would be regarded by astronomers of the future as the most valuable contribution that could be made to astronomy of the present day. Taken in conjunction with the astrographic survey of the heavens now so far advanced, it is an opportunity that if lost can never be made good ; a work that would grow in value year by year as time rolls on, and one that would ever be remembered with gratitude by the astronomers of the future.

But for the solution of the riddle of the universe much more is required. Besides the proper motions, which would be derived from the data just described, we need for an ideal solution to know the velocity in the line of sight, the parallax, the magnitude, and the spectrum-type of every star.

The broad distinction between these latter data and the determination of proper motion is this, that whereas the observations for proper motion increase in value as the square of their age, those for velocity in the line of sight, parallax, magnitude, and type of spectrum may, for the broader purposes of cosmical research, be made at any time without loss of value. We should therefore be most careful not to sacrifice the interests of the future by immediate neglect of the former for the latter lines of research. The point is that those observatories which undertake this meridian work should set about it with the least possible delay, and prosecute the programme to the end with all possible zeal. Three observatories in each hemisphere should be sufficient ; the quality of the work should be of the best, and quality should not be sacrificed for speed of work.

But the sole prosecution of routine labour, however high the ultimate object, would hardly be a healthy condition for the astronomy of the immediate future. The sense of progress is essential to healthy growth, the desire to know must in some measure be gratified. We have to test the work that we have done in order to be sure that we are working on the right lines, and new facts, new discoveries, are the best incentives to work.

For these reasons Kapteyn, in consultation with his colleagues in different parts of the world, has proposed a scheme of research which is designed to afford within a comparatively limited time a great augmentation of our knowledge. The principle on which his programme is based is that adequate data as to the proper motions, parallaxes, magnitudes, and the type of spectrum of stars situated in limited but symmetrically distributed areas of the sky, will suffice to determine many of the broader facts of the constitution of the universe. His proposals and methods are known to astronomers and need not therefore be here repeated. In all respects save one these proposals are practical and adequate, and the required co-operation may be said to be already secured—the exception is that of the determination of motion in the line of sight.

All present experience goes to show that there is no known satisfactory method of determining radial velocity of stars by wholesale methods, but

that such velocities must be determined star by star. For the fainter stars huge telescopes and spectroscopes of comparatively low dispersion must be employed. On this account there is great need in both hemispheres of a huge reflecting telescope—six to eight feet in aperture—devoted almost exclusively to this research. Such a telescope is already in preparation at Mount Wilson, in America, for use in the northern hemisphere. Let us hope that Professor Pickering's appeal for a large reflector to be mounted in the southern hemisphere will meet with an adequate response, and that it will be devoted there to this all-important work.

Conclusion.

The ancient philosophers were confident in the adequacy of their intellectual powers alone to determine the laws of human thought and regulate the actions of their fellow men, and they did not hesitate to employ the same unsupported means for the solution of the riddle of the universe. Every school of philosophy was agreed that some object which they could see was a fixed centre of the universe, and the battle was fought as to what that centre was. The absence of facts, their entire ignorance of methods of exact measurement, did not daunt them, and the question furnished them a subject of dispute and fruitless occupation for twenty-five centuries.

But astronomers now recognise that Bradley's meridian observations at Greenwich, made only 150 years ago, have contributed more to the advancement of sidereal astronomy than all the speculations of preceding centuries. They have learned the lesson that human knowledge in the slowly developing phenomena of sidereal astronomy must be content to progress by the accumulating labours of successive generations of men; that progress will be measured for generations yet to come more by the amount of honest, well-directed, and systematically discussed observation than by the most brilliant speculation; and that, in observation, concentrated systematic effort on a special thoughtfully selected problem will be of more avail than the most brilliant but disconnected work.

By these means we shall learn more and more of the wonders that surround us, and recognise our limitations when measurement and facts fail us.

Huggins's spectroscope has shown that many nebulæ are not stars at all; that many well-condensed nebulæ, as well as vast patches of nebulous light in the sky, are but inchoate masses of luminous gas. Evidence upon evidence has accumulated to show that such nebulæ consist of the matter out of which stars (*i.e.*, suns) have been and are being evolved. The different types of star spectra form such a complete and gradual sequence (from simple spectra resembling those of nebulæ onwards through types of gradually increasing complexity) as to suggest that we have before us, written in the cryptograms of these spectra, the complete story of the evolution of suns from the inchoate nebula onwards to the most active

sun (like our own), and then downward to the almost heatless and invisible ball. The period during which human life has existed on our globe is probably too short—even if our first parents had begun the work—to afford observational proof of such a cycle of change in any particular star; but the fact of such evolution, with the evidence before us, can hardly be doubted. I most fully believe that, when the modifications of terrestrial spectra under sufficiently varied conditions of temperature, pressure, and environment have been further studied, this conclusion will be greatly strengthened. But in this study we must have regard also to the spectra of the stars themselves. The stars are the crucibles of the Creator. There we see matter under conditions of temperature and pressure and environment, the variety of which we cannot hope to emulate in our laboratories, and on a scale of magnitude beside which the proportion of our greatest experiment is less than that of the drop to the ocean. The spectroscopic astronomer has to thank the physicist and the chemist for the foundation of his science, but the time is coming—we almost see it now—when the astronomer will repay the debt by wide-reaching contributions to the very fundamenta of chemical science.

By patient, long-continued labour in the minute sifting of numerical results, the grand discovery has been made that a great part of space, so far as we have visible knowledge of it, is occupied by two majestic streams of stars travelling in opposite directions. Accurate and minute measurement has given us some certain knowledge as to the distances of the stars within a certain limited portion of space, and in the cryptograms of their spectra has been deciphered the amazing truth that the stars of both streams are alike in design, alike in chemical constitution, and alike in process of development.

But whence have come the two vast streams of matter out of which have been evolved these stars that now move through space in such majestic procession?

The hundreds of millions of stars that comprise these streams, are they the sole ponderable occupants of space? However vast may be the system to which they belong, that system itself is but a speck in illimitable space; may it not be but one of millions of such systems that pervade the infinite?

We do not know.

'Canst thou by searching find out God? canst thou find out the Almighty unto perfection?'

REPORTS

ON THE

STATE OF SCIENCE.

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Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. F. W. RUDLER (*Secretary*), Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Dr. HORACE T. BROWN, Dr. VAUGHAN CORNISH, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Professor R. MELDOLA, Dr. H. R. MILL, Mr. C. H. READ, Rev. T. R. R. STEBBING, Professor W. W. WATTS, *and the* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

Applications have been received during the past year from six local Societies desirous of being brought into correspondence with the British Association. The Committee recommends that the following Societies, which issue publications containing the results of original scientific investigations, should be placed on the list of Affiliated Societies, namely :—

The Ashmolean Natural History Society of Oxfordshire.
The Worcestershire Naturalists' Club.

It is also recommended that the following bodies be placed on the list of Associated Societies, namely :—

The Maidstone and Mid-Kent Natural History Society.
The Scarborough Philosophical and Archæological Society.
The Bournemouth and District Society of Natural Science.
The School Nature-Study Union.

With regard to the Inverness Scientific Society, the Haslemere Microscope and Natural History Society, and the Leeds Naturalists' Club, which have hitherto been on the affiliated list, the Committee has to report that as these Societies have not published for some time past the results of any original work, they should be removed from the rank of Affiliated to that of Associated Societies. The latter are not necessarily publishing bodies, and do not receive the Annual Report of the Association.

Your Committee has had under consideration a suggestion, made by the Delegates at last year's Conference, with reference to the advisability of making application to the British Association for the appointment of a

Committee to promote and supervise County Photographic Surveys. The suggestion arose in the course of a discussion on a paper read at the Conference by Mr. W. Jerome Harrison. The Committee has been led to the conclusion that the proposal, as originally made, was too wide in scope and too vague in its objects to admit of action being profitably taken by the Association; but it believes that, while the scheme in its entirety seems impracticable, a Committee might advantageously deal with some specific branch of the suggested work. It has been thought that Archæology, in so far as it comes within the scope of the British Association, would be a subject that might appropriately be thus dealt with; and it has consequently been arranged that the matter shall be brought for discussion before the Conference at Leicester by the Rev. R. Ashington Bullen, who will introduce it by a paper 'On the Advisability of Appointing a Committee for the Photographic Survey of Ancient Remains in the British Islands.'

It has been suggested by the British Mycological Society, which has recently been brought into relation with the British Association, that the investigation of Fungi should receive more attention from local Societies. This suggestion having been favourably received, the Committee has decided that the subject be submitted to the Delegates at Leicester, when a paper intended to encourage the study of the group of fungi will be read by Mr. Carleton Rea, of Worcester.

Mr. H. J. Mackinder, who will preside at the Conference at Leicester, has promised to deliver an introductory address to the Delegates on 'The Advancement of Geographical Science by Local Scientific Societies.'

The Cardiff Naturalists' Society reports that, as a consequence of Dr. H. R. Mill's suggestions in the paper which he read before the Delegates last year, the Society has presented to the Cardiff City Council three meteorological instruments to complete the equipment of the local station. Your Committee regards this as a very satisfactory result of the last Conference.

More than thirty volumes of the Proceedings of the local Corresponding Societies have recently been bound and added to the collection which is preserved for consultation in the office of the British Association.

Your Committee asks for reappointment with a grant of 25*l*.

Report of the Conference of Delegates of Corresponding Societies held at Leicester, August 1 *and* 6, 1907.

Chairman	. H. J. Mackinder, M.A.
Vice-Chairman	. Rev. J. O. Bevan, M.A.
Secretary	. F. W. Rudler, I.S.O.

The following Corresponding Societies nominated Delegates to represent them at the Conference. The attendance of Delegates is indicated in the list by the figures 1 and 2 placed in the margin opposite to the name of the Society, and referring respectively to the first and second meetings. Where no figure is shown it will be understood that the Delegate did not attend. The attendances are taken from the Attendance-Book, which each Delegate is expected to sign on entering the Meeting-Room.

List of Affiliated Societies appointing Delegates.

2	Andersonian Naturalists' Society	M. B. Gilmour, F.Z.S.
2	Ashmolean Natural History Society of Oxfordshire	F. A. Bellamy, M.A.
2	Bath Natural History and Antiquarian Field Club	Rev. C. W. Shickle, M.A.
2	Belfast Natural History and Philosophical Society	John Smyth, M.A.
2	Belfast Naturalists' Field Club	Mrs. Mary Hobson.
2	Berwickshire Naturalists' Club	G. P. Hughes, F.R.G.S.
	Birmingham and Midland Institute Scientific Society	C. J. Watson.
	Birmingham Natural History and Philosophical Society	C. J. Watson.
2	Brighton and Hove Natural History and Philosophical Society	Alfred W. Oke, LL.M.
	Bristol Naturalists' Society	J. H. Priestley.
	British Mycological Society	V. H. Blackman, F.L.S.
	Buchan Field Club	J. F. Tocher, F.I.C.
	Burton-on-Trent Natural History and Archæological Society	B. L. Oswell.
	Canada: Royal Astronomical Society	Prof. A. T. de Lury, M.A.
	Caradoc and Severn Valley Field Club	Prof. W. W. Watts, F.R.S.
	Cardiff Naturalists' Society	Prof. W. S. Boulton, B.Sc.
	Chester Society of Natural Science, Literature, and Art	F. W. Longbottom, F.R.A.S.
2	Cornwall Royal Polytechnic Society	E. Kitto, F.R.M.S.
2	Croydon Natural History and Scientific Society	W. Whitaker, F.R.S.
	Dorset Natural History and Antiquarian Field Club	Alfred Pope.
	Dublin Naturalists' Field Club	G. H. Carpenter, B.Sc.
	Dumfriesshire and Galloway Natural History and Antiquarian Society	Prof. G. F. Scott-Elliott, M.A.
	East Kent Scientific and Natural History Society	A. S. Reid, M.A.
	Eastbourne Natural History Society	H. Dent Gardner, F.R.G.S.
	Edinburgh Field Naturalists' and Microscopical Society	W. C. Crawford, F.R.S.E.
2	Edinburgh Geological Society	R. C. Millar.
2	Essex Field Club	F. W. Rudler, I.S.O.
2	Glasgow Natural History Society	Peter Ewing, F.L.S.
2	Glasgow Royal Philosophical Society	David Ellis, D.Sc.
	Halifax Scientific Society	Wm. Simpson, F.G.S.
	Hampshire Field Club and Archæological Society	W. Dale, F.S.A.
	Hertfordshire Natural History Society and Field Club	Henry Kidner, F.G.S.
2	Hull Geological Society	G. W. Macturk.
	Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
2	Institution of Mining Engineers	J. A. Longden, M.Inst.C.E.
	Isle of Man Natural History and Antiquarian Society	G. W. Lamplugh, F.R.S.
	Leeds Geological Association	Prof. P. F. Kendall, M.Sc.
	Leeds Naturalists' Club	H. C. Marsh.
	Leicester Literary and Philosophical Society	Theodore Walker, F.R.G.S.
	Liverpool Biological Society	H. C. Beasley.
	Liverpool Geographical Society	Capt. E. C. Dubois Phillips.
	Liverpool Geological Society	H. C. Beasley.
	London: Quekett Microscopical Club	Joseph Wilson.

	2	Manchester Geographical Society	J. Howard Reed, F R G.S.
		Manchester Geological and Mining Society	William Watts.
		Manchester Microscopical Society	F. W. Hembry, F R M.S.
		Manchester Statistical Society	Prof. S J. Chapman, M.A.
	2	Midland Counties Institution of Engineers	J. A. Longden, M.Inst.C.E.
		Norfolk and Norwich Naturalists' Society	Frederick Long, L.R.C.P.
		North of England Institute of Mining and Mechanical Engineers	Rev. G M. Capell.
1	2	North Staffordshire Field Club	J. R. B. Masefield, M.A.
1	2	Northamptonshire Natural History Society and Field Club	H. N. Dixon, F.L.S.
1	2	Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society	G. P. Hughes, F.R.G.S.
1	2	Nottingham Naturalists' Society	Prof. J. W. Carr, M A.
1	2	Paisley Philosophical Institution	John Woodrow.
1		Perthshire Society of Natural Science	Dr. H. R. Mill, F.R.S.E.
1	2	Rochdale Literary and Scientific Society	J. R. Ashworth, D.Sc.
1	2	Somersetshire Archæological and Natural History Society	F. J. Clark, F.L.S.
1	2	South-Eastern Union of Scientific Societies	Rev. R. Ashington Bullen, B.A.
		Tyneside Geographical Society	Herbert Shaw, B.A.
		Vale of Derwent Naturalists' Field Club	H. F. Bulman.
1		Warwickshire Naturalists' and Archæologists' Field Club	W. Andrews, F.G.S.
1	2	Woolhope Naturalists' Field Club	Rev. J. O. Bevan, M.A.
1	2	Worcestershire Naturalists' Club	Carleton Rea, B.C.L.
		Yorkshire Geological Society	Wm. Simpson, F.G.S.
1		Yorkshire Naturalists' Union	T. Sheppard, F.G.S.
1	2	Yorkshire Philosophical Society	Richard Thompson.

List of Associated Societies appointing Delegates.

1	2	Bakewell Naturalists' Club	E. M. Wrench, M.V.O.
1	2	Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B.
1	2	Bournemouth and District Society of Natural Science	J. E. Liddiard, F.R.G.S.
1		Bradford Natural History and Microscopical Society	W. West, F.L.S.
		Catford and District Natural History Society	A. B. Harding.
1	2	Dover Sciences Society	Percy Moring.
		Dunfermline Naturalists' Society	Henry Beveridge.
		Ealing Scientific and Microscopical Society	Dr. W. Deane Butcher.
1	2	Grimsby and District Antiquarian and Naturalists' Society	O. T. Olsen, F.L.S.
1	2	Hampstead Scientific Society	C. O. Bartrum, B.Sc.
1		Hastings and St. Leonards Natural History Society	T. Parkin, M.A.
1	2	Ipswich and District Field Club	P. G. H. Boswell.
1		Lewisham Antiquarian Society	A. E. Salter, D.Sc.
1		Newcastle-upon-Tyne Literary and Philosophical Society	Prof. M. C. Potter, F.L.S.
		Preston Scientific Society	Edmund Dickson, F.G.S.

1		Scarborough Philosophical and Archæological Society	Herbert King, M.Sc.
1	2	School Nature Study Union	Mrs. White, D.Sc.
1	2	Southport Society of Natural Science	D. E. Benson.
		Teign Naturalists' Field Club	P. F. S. Amery.
1		Torquay Natural History Society	A. Somervail.
1	2	Tunbridge Wells Natural History and Philosophical Society	Rev. T. R. R. Stebbing, F.R.S.
		Watford Camera Club	John Hopkinson, F.L.S.

First Meeting, August 1.

The Meeting was presided over by Mr. H. J. Mackinder, M.A., Chairman of the Conference. The Corresponding Societies Committee was represented by the Rev. J. O. Bevan, Sir Edward Brabrook, Dr. H R. Mill, Mr. Rudler, the Rev. T. R. R. Stebbing, F.R.S., and Mr. Whitaker, F.R.S.

The Chairman delivered an address on 'The Advancement of Geographical Science by Local Scientific Societies.'

Chairman's Address.

The honour of presiding over your Conference has been conferred on me in order, as I understand, that I may have the opportunity of bringing before you the desirability of local geographical research in this country. From the fact that I live in London, I cannot pretend to offer any experience or useful advice either in the matter of the opportunities open to the Societies which you represent, or in regard to the difficulties which may beset them. How far what I am going to say may be practicable under your conditions it is for you to decide. My function, it appears to me, is to place before you an ideal, and to speak to you simply as a geographer. This much, however, I am entitled to say—that the work which I wish to commend to your attention has been accomplished in neighbouring countries, in some degree at any rate, by the co-operation of local agencies.

In France there are some twenty local Geographical Societies, there being one, with very few exceptions, in each of the old provincial centres. These Societies hold an annual conference, which resembles this Conference except that it is for geography only. Not a few geographical studies relating to different parts of France have emanated from these Societies, and have been published in the 'Annales de Géographie' and other journals. It is in part from these fragments that Vidal de la Blache has built up his admirable description of France in the introductory volume of the great history which is now being issued by Lavisse.

In Germany the same end is attained, although with slightly different machinery. There, as you know, university education is more markedly decentralised than in France, or even in Britain, with the result that scattered over the whole country there are geographical institutes of university rank whose professors and students have put together a rich geographical literature descriptive of every part of the land.

My suggestion is that in this country a similar work might be achieved by the co-operation of your Societies. It is true that we have a certain number of provincial Geographical Societies, but, with the exception of the Royal Scottish Geographical Society in Edinburgh, they are

situated in the great commercial centres, and devote themselves rather to the spreading of a knowledge of the lands beyond the seas than to the study of local British geography. Here again I must make a partial exception in the case of the Royal Scottish Geographical Society at Edinburgh; but I think that I have not misrepresented the very valuable aims and work of the Societies at Southampton, Manchester, Liverpool, and Newcastle, or of the branches of the Scottish Society at Glasgow, Aberdeen, and Dundee. In course of time the geographical teachers in our old and new universities may no doubt come to our aid, but there are wide areas of our country which have no university, or none sufficiently developed as at present to afford a Chair in Geography. For some time to come I see no agencies which can cover the United Kingdom consistently with centres of geographical study, unless they are to be found in the Societies which you represent.

Let me now give a first indication of the nature of the work which I am proposing. Many of your societies have members interested in botany, and in your publications there are not a few valuable memoirs dealing with the distribution of plant species. That of course was a very necessary study, but we are now developing a different study, whose object is to ascertain the distribution of what are known as plant associations. For instance, in the twenty-first and twenty-second volumes of the 'Geographical Journal' you will find maps showing the distribution of the plant associations of Yorkshire, which have been compiled from the researches of Mr. William G. Smith and others who have assisted him. Here you will see carefully mapped by Bartholomew the distribution of the various moorland, woodland, and farmland associations. For instance, under the head of moorlands you will find distinguished upon the map the bilberry summits, the cotton-grass bogs, the heather moors, the grass heaths, the natural pastures, and the lowland swamps. In each of these associations there are several characteristic plants, which occur together and very rarely apart—a fact which is obvious to anyone who contrasts the trees and undergrowth which constitute an oak wood with those which constitute a beech wood. Primarily, of course, the distribution of these associations is due to differences of climate and soil, but also it must be remembered that the dominant plants themselves form the required environment of the minor species associated with them. I commend to you the study of these maps themselves, for they will give you a far better idea of the nature and value of this kind of botanical geography than any mere description of mine. Admirable examples of the same kind of work are the memoirs and maps of the late Mr. Robert Smith, published in the sixteenth volume of the 'Scottish Geographical Magazine' under the title of 'A Botanical Survey of Scotland.' Results of this nature, I may point out, are however comparatively useless unless the different parts of the country are mapped according to a more or less uniform scheme; hence the value of the lead which such a conference as this may give to local societies.

The distribution, however, of plant associations is of comparatively little value when studied alone. We require for its interpretation a knowledge of the local land forms and drainage systems, of local drift geology, of local climate, and many other local data which can be expressed upon maps. The geographical method of research is to construct with scrupulous care separate maps of each of these orders of phenomena, and then to compare them, when correlations of distribution will leap to

notice and will suggest fresh inquiries. It is obvious that for the study of the causes of local distribution we must often go to historical records, whether embodied in documents, in place-names, or in archæological relics. My suggestion is that the distribution of all these things should be systematically studied upon the map. It is true, no doubt, that maps are attached to many special studies, botanical, geological, or archæological; but the research which I am suggesting treats the comparison of a large number of such maps as its main material, and is not satisfied with having them as incidental illustrations in books of non-geographical aim, and with having them prepared according to different methods, and therefore without facilities for comparison. In other words the object is to have a complete analysis of each district from a geographical standpoint.

We already have examples of the kind of work which I am indicating, although, as being the product in each case of one man's research only, they have not and cannot have the thoroughness and richness which would ensue from the combined and prolonged endeavour of one of your societies. Dr. H. R. Mill has described a small part of Sussex in his 'Fragment of the Geography of England' which you will find in the fifteenth volume of the 'Geographical Journal.' Dr. Herbertson, again, has a description of the Oxford Sheet of the One-inch Ordnance Survey Map in the first volume of the 'Geographical Teacher,' and Professor Geddes has given us descriptions of the neighbourhood of Edinburgh in connection with his Outlook Tower. But these essays, though excellent so far as they go, are hardly comparable with the elaborate Continental descriptions to which I have referred. No really adequate geographical account of the British Isles will be possible until we have a much richer local literature from which an author may mine. Yet such an account is essential to any scientific basis for British national history.

What is wanted is that in connection with each Society it should be the duty of some member to correlate the results obtained by the different specialist sections. This member would extract from the work of the botanists, the archæologists, the geologists, and others the data for the construction of his scheme of maps, and it would fall naturally to him to suggest the formation of new sections, and to enlist the enthusiasm of fresh students for the purpose of filling lacunæ in the local researches. In other words, it would be his special function to correlate from a geographical point of view the work of the various specialists, and to draw deductions from his correlations for the guidance of the specialists in their further work. Local investigation, instead of being haphazard and isolated, would thus become co-operative, and the results would be synthetic. Side-lights would be thrown on all manner of special studies, and the students of other sciences would thus get back with interest the contributions which they made to geography.

All this is easily said, but our experience shows that only a geographer of adequate training and insight could perform the function which we here demand. Such persons are no doubt increasing in number. The University Schools of Geography at Oxford and elsewhere are gradually supplying them, and before long it should be possible for each of your societies to find someone, say a master in some neighbouring public school, who is capable for the purpose. In some cases you may even have a member who would be willing to undergo the necessary training specially for your service.

I am aware, of course, that your Societies are perhaps more often than

not on a county basis, and many of our counties do not coincide with natural geographical units or groups of units. You have the same thing in France, where the natural 'pays,' such as Caux, Bray, Bresse, Bauce, Sologne, and so forth, bear distinctive names more frequently perhaps than in this country. Economy of effort should, in the case of certain counties at any rate, prompt an exchange of territory with adjoining counties. In Hampshire, for instance, the little strip of the Weald along the eastern border of the county could not be understood apart from the much larger Wealden areas of Surrey and Sussex, and the study of it might therefore very reasonably be separated from that of the great chalk plateau of Hampshire and Wiltshire. In other words, your societies might divide the land into countries analogous to the 'countries' hunted by the various packs of hounds, the Quorn, the Craven, and the rest of them.

Finally, I would suggest that any local Society which saw its way to organising and carrying through such a thorough and comprehensive survey as to lead to a geographical synthesis of all the aspects, physical and humane, of local knowledge would blend itself with the local life and establish itself securely among the local institutions. On all hands it is now agreed that education in such subjects as geography and history should be based on the study of the home district. What finer work for the efforts of a local Society than to produce a text-book for the local schools which shall rouse and satisfy interest in the surrounding countryside and in the local monuments, generate local patriotism, and establish an outlook into the larger world on a concrete foundation rather than on the sands of mere book learning? Such a text-book might also be correlated with the local museum arranged for visual instruction, and so classified as to prompt systematic thought. Of course I am not here advocating the incorporation into such an educational system of the occasional special collections, which have more than a local value and are visited by scholars from a distance.

The outcome of it all seems to me to be this: that while we can advance knowledge only by being specialists, yet we do require that in each important Society there should be one or more whose specialty consists in the correlation for the locality of all the other specialties; and, in my opinion, this correlation can best be accomplished on a geographical basis and by geographical methods

Captain Dubois Phillips (Liverpool Geographical Society), in proposing a vote of thanks to the Chairman, expressed his satisfaction that a geographical subject had at length been brought before the Delegates. He remarked that Geography as outlined by Mr. Mackinder was something vastly different from the general conception of that science. He hoped that the address would be printed, and copies forwarded to every Geographical Society in the country, as well as to the Scientific Societies in correspondence with the Association.

Dr. H. R. Mill (Perthshire Society of Natural Science), in seconding the vote of thanks, referred to the inspiriting character of the Chairman's discourse and the stimulus it would no doubt give to some individuals and Societies. He feared, however, that the complete realisation of Mr. Mackinder's scheme would not be effected in the lifetime of anyone present; still, one of the reasons for the existence of a Society was to carry out work that was too hard or too long for an individual.

The Rev. R. Ashington Bullen (South-Eastern Union of Scientific Societies) introduced the following subject:—

The Advisability of Appointing a Committee for the Photographic Survey of Ancient Remains in the British Islands.

Last year, at York, the Delegates had the advantage of listening to a clear, concise, and comprehensive paper by Mr. W. Jerome Harrison on the 'Desirability of Promoting County Photographic Surveys.' Nothing but good can come out of such a discussion as that paper initiated, and in one sense I am, so to speak, continuing that discussion, so that something of a practical character may result.

I have lately sought for some of the earliest references to the practical application of photography to scientific purposes, and the earliest which I could find dates back to the forties of the last century. In a book of J. L. Stephens's on 'Incidents of Travel in Yucatan' (in the year 1841) it is stated that 'the descriptions are accompanied by full-page illustrations from daguerreotype views and drawings taken on the spot by Mr. Catherwood, and the engravings were executed under his personal superintendence.' The object of that expedition was to visit the almost forgotten cities of Yucatan, and the work of faithfully reproducing the hieroglyphics and carved images must have been considerably aided even by the somewhat clumsy and uncleanly process of daguerreotyping.

Again, in 1859, when the too tempting rewards offered by Boucher de Perthes had caused many spurious flint implements to be included among the genuine work of palæolithic man, Prestwich called in the aid of photography, and by employing a photographer from Amiens he was able to exhibit photographs of palæolithic implements still *in situ* at St. Acheul, in the very pit from which remains of *Elephas primigenius*, *Rhinoceros tichorhinus*, &c., had been obtained.

Again, on the one hand how valuable would have been photographs of the seventeen inverted urns unearthed in cutting Fordingbridge Railway, of which Dr. Blackmore tells me no account has been published, nor illustrations given; and, on the other hand, how useful the photographs of the cists in the late Keltic cemetery at Harlyn Bay have proved, seeing that the human bones sent to Truro were so damp that most of them fell to pieces on the way thither.

I have always regretted that the prehistoric slate-built hut at Constantine Island, Cornwall, was never photographed before it was reduced to ruins by some unknown searcher for buried treasure. The treasure was there, but it was not of gold—only the cunningly placed hut of neolithic man upon an old raised beach. One could easily multiply instances of the utility of photography in furnishing valuable corroborative evidence; but let the above instances suffice.

There can only be one opinion as to the value of Mr. Jerome Harrison's suggestive paper, already referred to; but the work to which he invites the British Association is so vast that it would need a separate organisation in order to attain an adequate measure of success.

Such a work seems rather to be suitable for a Society like the 'National Photographic Record Association.' Since the British Association has members in every county of the British Isles it is believable that the inclusion of the subject of County Photographic Surveys for discussion at this meeting may help to advertise the desirability of such

comprehensive surveys, the work of which, if fully carried out, will necessarily include a great deal that is not to be ranged under the banner of Science, although quite worthy of being photographed and recorded for other reasons.

But although it may not be advisable for the British Association to undertake such a wide field of work it may be able to address itself to a more limited one by confining itself to the photographing of ancient remains in the British Islands.

If we refer to the British Association Reports for the last four years we shall find that Section H has not only dealt with such subjects as the stone circles and other prehistoric antiquities of the British Isles, but also with excavations on Roman sites and investigations of Anglo-Saxon remains in various places.

Here, then, we have a precedent in the work undertaken by an important section, and we might define the ancient remains which would come within the scope of any photographic enterprise as consisting of such remains as precede and include the Anglo-Saxon period. These might be justly comprised under the term 'archæology' as distinct from what is merely 'antiquarian.' So much remains still to be discovered about the peopling of these islands after the Roman domination ceased that the Anglo-Saxon period would form a fitting terminus for the photographic archæologist.

Several photographic committees have already been appointed by the British Association. One deals with geological photographs, another with those of anthropological interest, and a third with botanical photographs. The excellent work of these may well be supplemented by that of another committee appointed to deal with objects of the palæolithic, neolithic, bronze, late Keltic, Roman, and Anglo-Saxon epochs, apart from photographs relating to anthropometry and ethnography, if these are already included in the work of the Committee on anthropological photographs. There would thus be a permanent record of all photographs of the character indicated, and an annual exhibition of such photographs at the British Association meeting might well become a permanent feature of that annual gathering. So that, although it may not be possible, on account of the extensive organisation required and of the great expense involved, for the Association to co-ordinate all the county surveys by means of a central committee for photographic work, still it may be possible, if the delegates so determine, to form a photographic committee to deal with ancient British remains, requiring only a modest grant for expenses from the Association funds, and covering the ground not already preoccupied by the special committees, such as deal photographically with stone circles, geology, and anthropometry. The work of any such photographic committee would be considerably aided by the invaluable suggestions in the appendix to Mr. Jerome Harrison's thoughtful paper.

Mr. H. S. Kingsford (Section of Anthropology), speaking as Secretary of the Committee appointed by Section H to register anthropological photographs, drew the attention of the Conference to the work of this Committee, which included such work as that now proposed. He urged upon the delegates the advisability of their co-operating with this Committee rather than founding a new one, and particularly pointed out the disadvantage of two committees working for the same object, with inevitable overlap and loss of efficiency.

Mr. William Dale (Hants Field Club and Archæological Society) said that his Society had taken up the work of photographing objects of interest in his county, and an album of such photographs was in the possession of Mr. Nisbett of Winchester. It was of importance that local societies should undertake the work, inasmuch as they would have the best information about objects which were in danger of disappearing, a contingency which was continually occurring. The photographs should be readily accessible and placed where they could be seen by all. As an instance of a photographic surprise he mentioned the wonderful photographs of Stonehenge taken last year by Lieut. Capper from a war balloon.

Mr. Alfred Pope (Dorset Natural History and Antiquarian Field Club) said that with regard to the county which he represented, the advantages of a photographic survey had not been lost sight of. The Rev. Wm. Miles Barnes had, in connection with the Dorset Field Club, already procured some three thousand photographs, of a uniform size so far as possible, of subjects of antiquarian and historical interest in the county, which are preserved in four royal folio albums deposited in the county museum, where they are available for reference. It was his intention to obtain at once photographs of some well-formed 'linchets' in a common field now being enclosed, which would shortly disappear under the plough. All the old stone crosses in the county had also been photographed.

Mr. Thomas Parkin (Hastings and St. Leonards Natural History Society) drew attention to the fact that a photographic society had been for some years established in Sussex for the purpose of taking views of ancient buildings and interesting spots, some of which were fast vanishing. The Society places these photographs on view on all possible occasions.

Mrs. Mary Hobson (Belfast Naturalists' Field Club) said that in the Society which she represented there were many members who had taken much pains to photograph and make plans of prehistoric remains. It was most important that records should be prepared without delay, for the monuments were fast disappearing.

Mr. Edward Kitto (Royal Cornwall Polytechnic Society) thought the subject under discussion one which would commend itself to the Society which he represented, especially as Cornwall is peculiarly rich in ancient stone memorials. It was painfully true that such monuments were rapidly disappearing, and he would suggest that those who were keen on securing photographs of these memorials might go further and assist in the preservation of these invaluable relics of the past.

Mr. Sheppard (Yorkshire Naturalists' Union) referred to a recent report that a well-known stone memorial in Cornwall had been broken up for road-metal. He pointed out that the work of the suggested Committee need not interfere with that of any existing Committee, but would rather supplement their work.

Mr. J. F. Tocher (Buchan Field Club) remarked that the part of the country he came from was rich in ancient monuments, and several excellent photographs had been taken of them under the auspices of the Buchan Field Club. He suggested that a Committee should be appointed by the delegates to act in conjunction with the Anthropological Section for photographing the ancient monuments of the Kingdom. It would be a pity if two separate committees acting under the wing of the British Association should be formed throughout the country.

After some further discussion it was resolved that the following resolution, proposed by Mr. Jerome Harrison, should be sent to the

Committee of Recommendations for transmission to the Council of the Association :—

That it is advisable :

1. To obtain information as to the present state of things in Britain in connection with Photo-Survey Work.

2. To publish instructions or give advice for the execution of a Scientific Photographic Survey.

3. To endeavour to found, or promote, a Photo Record of the town and district in which the British Association holds its Annual Meeting.

The Report of the Corresponding Societies Committee was read by the Secretary, and it was resolved to apply for a grant of 25*l.*

Second Meeting, August 6.

The Meeting was presided over by the Rev. J. O. Bevan, M.A., Vice-Chairman.

The Corresponding Societies Committee was represented by Mr. Bevan, Sir Edward Brabrook, Mr. Rudler, the Rev. T. R. R. Stebbing, and Mr. W. Whitaker.

The Vice-Chairman apologised for the absence of Mr. Mackinder (who had been called away on important business), and, in his name, welcomed the delegates to the second session. He lamented the facts that the delegates had but little time to make each other's acquaintance ; that they were unable to meet but for two short sessions, at the period of the annual gathering ; and that the *personnel* of the Conference materially changed from year to year, so that the interest excited had a tendency to die down and become extinguished. He asserted that the Corresponding Societies Committee were very sensible of these disadvantages, and were willing to adopt any suggestion whereby they might be counteracted. In face of the disabilities above mentioned, he ventured to impress upon the delegates the responsibility which rested upon them to take an active part in the proceedings of the Conference ; to make known to its members any branch of scientific work carried out by the bodies they respectively represented ; and, in turn, to report to their societies the main results arrived at in the various sectional meetings (or such portion as might particularly affect their locality), especially the suggestions for local work made at this conference by the Recorders of the various sections. He concluded by saying that in this way the British Association would fulfil its functions—of stimulating workers in the various departments of research, of popularising science and scientific method, and of exercising a co-ordinating influence over the various Societies whose representatives he had the honour of addressing.

Mr. Carleton Rea, B.C.L., M.A. (Worcestershire Naturalists' Club), then introduced the following subject :

A Plea that Local Societies should give greater attention to the investigation of the Fungi occurring in their Districts, with Suggestions for the Encouragement of the Study of this Group.

As the suggestion of the subject for discussion to-day originated with myself on behalf of the British Mycological Society, I felt, as their honorary Secretary, bound to accept the invitation of the Corresponding

Societies Committee to attend and expound our views with regard to it. The fact that the Committee has selected this topic for debate evidently indicates that it considers that most of our Local Societies neglect the investigation of the Fungi occurring in their districts. But what is the cause of this neglect? Thousands of species are at hand, and abound in every district, but our British botanists generally omit them from their enumeration of the plants occurring in the various county floras, and if they are in a few instances included, the task has been delegated to some outsider who cannot possibly have that intimate local knowledge which is necessary for the production of a complete and exhaustive list.

Why the study of our fungi has been so sadly neglected it is very hard to explain, because, unlike that of mosses and lichens, it is of immense importance to every individual. All our farmers and gardeners suffer immense losses annually, and I may mention incidentally that the International Phytological Commission in 1893 reported that the cereal rusts alone cost Prussia for that year 20,900,000*l*. A knowledge of this interesting group of plants also would place at the disposal of our people a great quantity of valuable nitrogenous food, which is at the present time allowed to fall into decay uncared for. It is only necessary to draw attention to these points to convince Local Societies that they should encourage the study of the fungi in their districts.

In 1868 the Woolhope Naturalists' Field Club inaugurated a series of autumnal forays, which were continued with some measure of success down to the year 1902, and these were copied by many of our leading Naturalists' Clubs. But the devotion of a day or even of a week in the autumn will not elucidate the fungi occurring in a given area. To do so satisfactorily it is necessary to investigate them year in and year out, and to place them on exhibition from day to day.

This exhibition should either be maintained in the Club Room or, better still, at the Local Museum, if the place possesses one, and should be open to the inspection of the general public.

Of course members of the Local Societies would willingly aid in bringing in specimens for the exhibition, but in order to stimulate the general public, and possibly the members also, it might be advisable to offer prizes for the most varied or most correctly named specimens sent in during the course of the year.

The Local Society should also annually prepare a list of the fungi, with the name of the finder, the exact habitat and locality, and encourage the general public to make accurate paintings, accompanied by accurate sections and microscopic details, if possible to one scale. The most convenient way of exhibiting the larger fleshy fungi and plant diseases is to display specimens on large plates, whilst the smaller ones should be inserted in tubes before being put on the plates. The label would give its correct scientific name, but the popular name, if it possessed one, should also be given, and an instructive note added. Thus:—

Amanita mappa (Batsch.). Fr. Very poisonous.
Hygrophorus psittacinus (Schaeff.). Parrakeet Mushroom. Edible. Delicious.
Exoascus pruni (Fckl.). Pocket-plums. Prune back behind the point of infection.

Two copies of the British Museum 'Guide to Sowerby's Models of

British Fungi' should be cut up and pasted on cards; these make instructive labels for those species to which they apply, and should be pinned out on the table in front of the plate containing the specimens. During the winter the exhibition would consist principally of wood-destroying fungi and moulds, and as many of the former are of a hard woody texture they can easily be displayed for some time, and sections of various trees showing their destructive influence on the wood can be exhibited alongside. In the spring and early summer the Fungi inducing various plant-diseases can be exhibited, accompanied by a note as to their treatment, and then in the autumn we have the abundant harvest of the year. To further popularise the study, short papers should be given to the members and the general public, and the arrangement of the groups into which this vast family of plants is divided should be explained, so that all may be easily conversant with the terms employed in describing these plants For many of the systematic works and text-books plunge at once *in medias res* without explaining the nature of the classification adopted or the meaning of the technical terms used.

Up to this point we have presumed that the Local Society possessed a member or members capable of determining the different species of fungi sent in from time to time, or that the Local Curator was competent to discharge that function. But if the Local Society have no members who are interested in this branch of botany, then we consider that the Local Society should persuade some member or members to take up the study of this neglected group. A botanist would find no difficulty in the study, as the orders and genera are very clearly defined, and are almost more easily determined than in the case of our flowering plants. And to ensure rapid progress in the study it would be well for those members to join and attend the annual meetings of the British Mycological Society. This Society holds a week's fungus foray every year in different parts of Britain, generally on the invitation of some Local Society. The specimens collected from day to day are named and placed out on exhibition, and ample time is allowed to the members to study them and to compare them with the descriptions in books.

Such exhibitions as we have advocated have been held for portions of the year both at Haslemere and Worcester with great success. The exhibitions have been very popular, and have diffused a pretty general knowledge of the subject. This I have proved in the case of the Worcestershire Naturalists' Club, where attention is paid to the study of fungi at all their meetings during the year, for the members easily follow a paper on the subject which other Local Societies that I have ventured to address have acknowledged to be beyond their comprehension.

Mr. H. N. Dixon (Northamptonshire Natural History Society and Field Club) explained that the collection of hand-coloured photographs exhibited in the ante-room was made by Mr. Albert Wallis, of Kettering, during the autumn of 1906 and the following months. It was shown at a meeting of the Northants Natural History Society, and he (the speaker), on hearing that the subject of the systematic study of Fungi would be introduced at this Conference, asked Mr. Wallis to allow the collection to be exhibited. He would be glad of suggestions by which such a collection might be made more complete and accurate for such a purpose as Mr. Carleton Rea had in view. He suggested the sending of

a leaflet to the Societies, giving suggestions and instructions as to the observations and data necessary for the identification of fungi, and also mentioning the names of gentlemen willing to act as referees. If the photographing of a specimen and the taking of such observations were made a preliminary condition of obtaining the help of the referee, it would prevent improper advantage being taken of such assistance. A photographic reproduction (coloured) answered the purpose of either a model or a painting of a fungus, with even less labour and greater accuracy in detail.

Mr. J. E. Liddiard (Bournemouth and District Society of Natural Science) remarked that the Society which he represented had done something to promote the study of Fungi, and he handed in a publication showing what his Society, in conjunction with the New Forest Society, had done in their district.

Mr. J. R. B. Masefield (North Staffordshire Field Club) called attention to the importance of the study of fungi to the farmer and gardener. Expert help, however, was required by Field Clubs. Photographs would be useful in assisting in the identification of species. It was important that there should be an interchange of views between the various Societies and mutual help given by arranging joint meetings.

Mr. P. Ewing (Glasgow Natural History Society) said that in his opinion the practice which obtained in the Society which he represented was a very satisfactory one—that of forming sectional committees. Only a few members in most Societies take a working interest in the different branches of science, and consequently those who take the most active part are made conveners of the various sections, to whom all specimens can be referred for identification. Such members can, as a rule, name correctly 98 per cent. of the specimens submitted, and for the sake of local records are quite willing to do so. More critical species, or those in which identification was doubtful, are referred to some authority. This authority, in the case of fungi, should be one recommended by the British Mycological Society.

Mr. G. P. Hughes (Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society) pointed out the desirability of including the study of Fungi in the list of scientific subjects to be introduced for the occasional instruction of children, especially in country schools, the importance of elementary scientific knowledge being very properly advocated by most of the sections of the British Association.

Mr. A. W. Oke (Brighton and Hove Natural History Society) referred to the educational value of the exhibition of living specimens of Fungi by Natural History Societies and Museums.

The Rev. T. R. R. Stebbing (Tunbridge Wells Natural History Society) observed that the annual exhibition of wild flowers, which excited much admiration at Tunbridge Wells, and which had been imitated in some other localities, was, in fact, only indirectly due to the Natural History Society. It had been initiated and carried on year by year by the personal efforts of Mr. Fred Roberts, an honoured assistant of that Society. This rather pointed to the desirability of securing the services of some enthusiastic member when any special work was to be done, in preference to asking vaguely for the efforts of a whole Society. Most likely Mr. Roberts, if requested to do so, would add the Fungi of the district to his much appreciated botanical exhibition.

The Rev. C. W. Shickle (Bath Natural History and Antiquarian Field Club) instanced the assistance given to the study of local Fungi by the valet of the late Mr. Skrine, of Warley.

Mr. W. Bell (Leicester Literary and Philosophical Society and delegate from Section K) spoke of the general ignorance in regard to the poisonous and edible forms of Fungi, and thought a closer study of the family would do much to remove the present prejudice. It was a most desirable thing to have a complete series of all plants, including Fungi, in County Herbaria. Hitherto the collection of Leicestershire plants, which contained from twenty thousand to twenty-five thousand sheets, had not more than a dozen forms of Fungi. This was due to the fact that great difficulty obtained in regard to the preservation of the specimens. He strongly recommended that, where it was impossible to preserve actual specimens, coloured photographs, such as those exhibited, should be filed.

Mr. J. A. Longden (Institution of Mining Engineers) said that he had never been able to eat mushrooms, for they were absolutely poisonous to him. It was important that the school children should be taught which mushrooms are edible for the ordinary mortal.

The Rev. R. Ashington Bullen (South-Eastern Union of Scientific Societies) said that there was no doubt a large quantity of nourishing material neglected in England. In Italian markets, he believed, there was an inspector of Fungi, who decided whether the species exposed for sale were edible; quite a large number are available for human food, although a fungus diet does not suit every person. Following the old proverb *fiat experimentum*, &c., his *corpus vile* had enjoyed, when he lived in Kent, *Clavaria* of various species, and the 'fairy-ring' fungus, *Marasmius* (superior in flavour to the ordinary mushroom); and in Hunts he had eaten *Agaricus* (*Psalliota*) *arvensis* and slices of young giant puff-balls, which in point of tastiness he considered equal to beef-steak.

The Rev. T. R. R. Stebbing called attention to a recent article in the 'Museum Gazette,' under the editorship of Dr. Jonathan Hutchinson, F.R.S. This article not only strongly insisted on the dangers involved in eating Fungi, but also maintained that, however agreeable they might be to the palate, they were almost entirely devoid of nutritious quality.

Mr. F. W. Rudler (Essex Field Club) remarked that the Society which he represented had always taken much interest in the study of Fungi. Ever since its foundation it had held annually a fungus foray, and in this way had registered pretty completely the fungus flora of Epping Forest. The next foray would probably take place in the woods around Chelmsford. Moreover, the Museums under the Essex Field Club exhibited models and coloured illustrations of Fungi, seeking by such means to explain to the public the differences between edible and poisonous species.

Professor J. W. Carr (Nottingham Naturalists' Society) pointed out the practical difficulties in working out the fungus flora of any district by the Local Society, owing to the general lack of expert knowledge of the plants of this group by the members of such Societies. He suggested that much good might be done if an expert mycologist, such as the opener of the discussion, would undertake to give an address on the best methods

of investigation of the Fungi before some of the principal local Natural History Societies in the country.

Mr. Carleton Rea, in reply, said that photographs *per se* were not good enough to identify the larger Fungi. The excellent coloured photographs exhibited by Mr. Wallis were much better, but their value from a scientific standpoint would be much enhanced by having a section cut longitudinally represented with each specimen, and the colour of the spores and their shape should also be set out, magnified to a constant increment of, say, 1000. He admitted that there were some persons who were unable to digest even the common mushroom, as was the case with certain people who were unable to assimilate pork or fish. But if people became mycophagists before they were competent mycologists, then they must be very careful to gather their specimens with the base of the stem intact, because, if they observed any trace of a universal wrapper, known as a volva, at the base of the stem they should reject it, as it was the dangerous *Amanitæ* and *Volvariæ* that possess this poison cup.

Professor Carr had said that it involved great research and high microscopic investigation to determine the species, but he reminded him that Parliament had just passed an Act which empowered the police to deal with plant diseases in the same way as they did with anthrax and swine fever, and therefore the police would have to determine whether the gooseberries were attacked by *Sphærotheca Mors-uvæ*. The continuous exhibition which he had advocated for popularising the knowledge of our Fungi could be carried on in conjunction with the exhibition of their wild flowers. At the present time at Worcester he had out on exhibition a far more virulent disease of the gooseberry than that caused by *Sphærotheca Mors-uvæ*, namely, *Leptosphæria vagabunda* (Sacc.), the conidial condition being a *Coniothyrium*. In conclusion he urged that it was the duty of all Local Societies to determine the Fungi of their own districts, and only when their mycologists were puzzled should they submit the specimens to a referee.

Reports from the Sections.

The Chairman then invited any Delegates from the Sections to explain how the Corresponding Societies could assist in aiding the work of the Committees of the several Sections.

Dr. W. N. Shaw, representing Section A (*Mathematics and Physics*), explained that he had only recently been informed of his appointment as the representative of that Section. There are many ways in which the Corresponding Societies could be helpful in the meteorological work in which he was specially interested.

Mr. C. O. Bartrum (Hampstead Scientific Society) reported that, as a result of Dr. Mill's suggestion at the last year's Conference, his Society had asked the London County Council for a site on the summit of Hampstead Hill for the establishment of a Meteorological Station; that the Council had granted the use of a site, and that by next year it was likely that the station would be in working order.

Dr. Theodore Groom (Section C, *Geology*) wrote that the Committee of the Section had decided to recommend to the Corresponding Societies

that the local work connected with the Section should embrace the following:—

i. Further investigations on Drift.
ii. The watching of new sinkings and borings, and the examination of cores.
iii. The collecting of local terms applicable to geology and geography.

Mr. W. Whitaker supported this recommendation, and especially solicited the aid of Provincial Societies in recording the meaning of local terms applied to geological objects.

Mr. Wilfred Mark Webb (Section D, *Zoology*) asked the representatives of the Corresponding Societies for help in connection with the distribution of Centipedes and Millepedes. He offered to send a booklet and collecting-tubes to anyone who would send him specimens, on application to him at Odstock, Hanwell, London, W The results will be published by the Ray Society in a monograph.

The Rev. T. R. R. Stebbing expressed a hope that Mr. Webb's request for centipedes would meet with a better response than his own often-repeated petition for well-shrimps had received. Of these the Delegates had never sent him any, although it is certain they are to be found in many parts of the kingdom. He further pointed out that in Section D, judging by the size of the audiences, far greater interest had this year been shown in Mendelian experiments than in any other subject.

Mr. E Heawood (Section E, *Geography*) wrote that his Committee could add nothing to the suggestions made by Mr. Mackinder in his address in connection with the work of Local Societies.

Mr. H. E. Wimperis (Section G, *Mechanical Science*) said that he had been instructed by his Committee to attend the meeting as a mark of their general sympathy. Owing, however, to the nature of their work they did not feel empowered to offer the Conference any suggestions.

Mr. G. L. Gomme (Section H, *Anthropology*) urged the local societies to organise a scheme for the photographing of ascertained types of local population. It was not too late to do this, for there were still people who had never left their villages, who had married inside their villages, and who were descendants of many generations of villagers. It was essential to select those persons whose names were to be found in the parish registers of as early a date as possible, and to take the photographs on a plan which should be common to all the counties. A collection of such photographs, possible now, would be impossible a few years hence, and one of the most fruitful means of identifying local ethnological types will have become destroyed without a record. The interest of such a collection would be enormous. The comparison of the various types would provide important ethnological data. Mr. Gomme mentioned the case of a village in Bucks where he had a cottage, and where two or three family names appeared over and over again, dating from the earliest times of the parish registers. The type of face was most distinctive for the men, and was of almost classical perfection; not so distinctive for the women, and not so perfect in form. He was certain that this meant something in the history of the Buckinghamshire village. The same kind of evidence repeated in the villages of every county where distinction and the necessary amount of evidence were forthcoming would be of the utmost value. On behalf of Section H he urged this im-

portant piece of work for early attention by the Local Societies, and he could assure the Conference of the gratitude of the Section on whose behalf he spoke.

Sir Edward Brabrook supported Mr. Gomme's appeal.

Miss Kate Stevens (Teachers' Guild) remarked that though she had no authority or instructions to speak on behalf of Section L (*Education*) she would urge all the members of the Conference to watch carefully the proceedings of the present Educational legislation, as radical changes had lately been made, without, in her opinion, sufficient notice or discussion.

Mr. F. A. Bellamy (Ashmolean Nat. Hist. Soc. of Oxfordshire) suggested that means should be taken to secure a better exchange of publications between scientific societies. After brief remarks by several delegates the further discussion of the subject was adjourned.

A vote of thanks was then passed to the Rev. J. O. Bevan as vice-chairman.

The Corresponding Societies of the British Association for 1907–1908.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Technical College, Glasgow. R. Barnett Johnstone and Arch. Park	322	None	2*s.* 6*d.*	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1880	F. A. Bellamy, 4 St. John's Road, Oxford	351	None	5*s.*	Report, annually.
Bath Natural History and Antiquarian Field Club, 1855	J. Langfield Ward, Royal Literary and Scientific Institution, Bath	60	5*s.*	10*s.*	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. R. M. Young, M.R.I.A.	210	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Museum, College Square. W. H. Gallway	410	5*s.*	5*s.*	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Rev. J. J. M. L. Aiken, B D., Manse of Ayton, Berwickshire	400	10*s.*	8*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	132	None	10*s.* 6*d.* and 5*s.*	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. W. B. Grove, M.A., and H. G. Perkins	190	None	1*l.* 1*s.*	Proceedings, occasionally.
Brighton and Hove Natural History and Philosophical Society, 1854	J. Colbatch Clark, 9 Marlborough Place, Brighton	160	None	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	J. H. Priestley, B.Sc., University College, Bristol	160	5*s.*	10*s.* and 5*s.*	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	70	None	10*s.*	Transactions, annually.
Buchan Field Club, 1887	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	170	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	H. Lloyd Hind, B.Sc., 55 Stanton Road, Burton-on-Trent	200	None	5*s.*	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto. J. R. Collins	400	None	2 dollars	Journal, bi-monthly.
Caradoc and Severn Valley Field Club, 1893	H. E. Forrest, 37 Castle Street, Shrewsbury	202	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	W. Gilbert Scott, 25 Duke Street, Cardiff	400	None	12*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln and F. Simpson	1073	None	5*s.*	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	The Museum, Public Buildings, Penzance. John B. Cornish	98	None	1*l.* 1*s.*	Transactions, annually.
Cornwall Royal Polytechnic Society, 1833	E. W. Newton, Camborne, Cornwall	300	None	10*s.* upwards	Report, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. G. W. Moore	167	None	10*s.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., M.R.A.S., Milton Abbey Vicarage, Dorset	400	10*s.*	10*s.*, 8*s.*, and 2*s.* 6*d.*	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	J. de W. Hinch, National Library of Ireland, Dublin, and F. O B. Ellison, M.D.	130	5*s.* Assoc. none	5*s.* Associate 2*s.* 6*d.*	'Irish Naturalist,' monthly; Report, annually.

Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	S. Arnott, Sunnymead, Dumfries	212	None	5s.	Transactions and Proceedings, annually
East Kent Scientific and Natural History Society, 1857	A. Lander, The Medical Hall, Canterbury	97	None	10s. and 5s.	Transactions, annually.
Eastbourne Natural History Society, 1867	Henry Sparks, Villa Ruhe, 5 St. Leonard's Road, Eastbourne	120	2s. 6d.	7s. 6d.	Transactions, biennially.
Edinburgh Field Naturalists' and Microscopical Society, 1869	John Thomson, 21 St. Ninian's Terrace, Edinburgh	230	5s.	5s.	Transactions, annually.
Edinburgh Geological Society, 1834	India Buildings, Edinburgh. David Gloag	243	10s. 6d.	12s. 6d.	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	Norris Mackay, W.S., Elgin	196	None	5s.	Transactions, occasionally.
Essex Field Club, 1880	William Cole, Springfield, Epping New Road, Buckhurst Hill, Essex	390	None	15s.	'Essex Naturalist,' quarterly; 'Year-book,' annually; 'Special Memoirs,' &c., occasionally.
Glasgow, Geological Society of, 1858	Peter Macnair, F.R.S.E., 207 Bath Street, Glasgow	300	None	10s.	Transactions, biennially.
Glasgow, Natural History Society of, 1851	Alex. Ross, 409 Great Western Road, Glasgow	295	None	7s. 6d.	Transactions and Proceedings, annually.
Glasgow, Royal Philosophical Society of, 1802	Prof. Peter Bennett, 207 Bath Street, Glasgow	1,000	1l. 1s.	1l. 1s.	Proceedings, annually.
Halifax Scientific Society, 1874	F. Barker, 11 Hall Street, Halifax	143	None	2s. 6d.	——
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	None	7s. 6d.	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	A. E. Gibbs, F.L.S., St. Albans, and A. Sutton, Watford	160	10s.	10s.	Transactions, twice a year.
Holmesdale Natural History Club, 1857	G. F. Pollard, F.Z.S., 170 Station Road, Redhill	94	None	10s. and 5s.	Proceedings, every two or three years.
Hull Geological Society, 1887	J. W. Stather, F.G.S., Newland Park, Hull	72	None	5s.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	T. Stainforth, The Museum, Hull	180	None	5s.	Transactions, annually.
Institution of Mining Engineers, 1889	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	3,300	None	None	Transactions, monthly.
Ireland, Statistical and Social Inquiry Society of, 1847	W. Lawson, Dr. N. M. Falkiner, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1l.	Journal, annually.
Leeds Geological Association, 1873	E. Hawkesworth, Crossgates, Leeds	87	None	5s.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. W. A. Evans, 24 Fosse Road South, Leicester	350 Membs. & Associates	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions, half-yearly.
Liverpool Biological Society, 1886	J. A. Clubb, M.Sc., Free Public Museum, Liverpool	95	10s. 6d. and 2s. 6d.	1l. 1s. and 10s. 6d.	Proceedings and Transactions, annually.
Liverpool Engineering Society, 1875	R. C. F. Annett, 4 Buckingham Avenue, Sefton Park, Liverpool	550	None	1l. 1s. and 10s. 6d.	Transactions and Report, annually.
Liverpool Geographical Society, 1891	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Bldgs., Liverpool	640	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions and Report, annually.
Liverpool Geological Society, 1858	Royal Institution. W. A. Whitehead, B.Sc.	70	None	1l. 1s. and 10s. 6d.	Proceedings, annually.
London: Quekett Microscopical Club, 1865	W. B. Stokes, 4 Winn Road, Lee, S.E.	402	None	10s.	Journal, half-yearly.
Man, Isle of, Natural History and Antiquarian Society, 1879	Armitage Rigby, 23 Athol Street, Douglas, Isle of Man	111	2s. 6d.	7s. 6d. and 5s.	Proceedings, three times a year; Transactions, occasionally.
Manchester Geographical Society, 1884	F. Zimmern and J. H. Reed, 16 St. Mary's Parsonage, Manchester	600	None	Members 1l. 1s.; Associates 10s. 6d.	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Sydney A. Smith	300	None	2l. 2s., 1l. 5s., 1l. 1s., and 1l.	Transactions of Inst. of Mining Engineers, monthly.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Manchester Microscopical Society, 1880	E. C. Stump, Malmesbury, Polefield, Blackley	217	5*s*.	6*s*.	Transactions and Report, annually.
Manchester Statistical Society, 1833	Theodore Gregory, 3 York Street, Manchester	191	10*s*. 6*d*.	10*s*. 6*d*.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlborough College. E. Meyrick, F.R.S.	280	1*s*. 6*d*.	3*s*. and 5*s*.	Report, annually.
Midland Counties Institution of Engineers, 1871	G. Alfred Lewis, M.A., Albert Street, Derby	420 Membs., Associates & Students	1*l*. 1*s*. None	Members 31*s*. 6*d*.; Associates and Students 20*s*.	Transactions of Institution of Mining Engineers, monthly.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	L. T. O'Shea, The University, Sheffield	306	None	1*l*. 10*s*.	Transactions of Inst. of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	W. A. Nicholson, St. Helen's Square, Norwich	277	None	6*s*.	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,350	None	25*s*. and 42*s*.	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865	W. Wells Bladen, Stone, Staffs	527	5*s*.	5*s*.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	H. N. Dixon, M.A., 23 East Park Parade, Northampton	210	None	10*s*.	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. N. H. Martin, F.L.S., and C. E. Robson	430	None	21*s*.	Transactions, annually.
Nottingham Naturalists' Society, 1852	Prof. J. W Carr, M.A., University College, Nottingham	182	2*s*. 6*d*.	5*s*.	Report and Transactions, annually.
Paisley Philosophical Institution, 1808	J. Gardner, 3 County Place, Paisley	570	5*s*.	7*s*. 6*d*.	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867	Tay Street, Perth. S. T. Ellison	390	2*s*. 6*d*.	5*s*. 6*d*.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	J. Reginald Ashworth, D.Sc., 105 Freehold Street, Rochdale	244	None	6*s*.	Transactions, biennially.
Rochester Naturalists' Club, 1878	John Hepworth, Linden House, Rochester	163	None	5*s*.	'Rochester Naturalist,' quarterly.
Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. F. W. Weaver, Rev. E. H. Bates, and C. Tite	676	10*s*. 6*d*.	10*s*. 6*d*.	Proceedings, annually.
South African Philosophical Society, 1877	G. M. Clark, South African Museum, Cape Town	207	None	2*l*.	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	Rev. R. Ashington Bullen, B.A., Englemoor, Heathside Road, Woking	49 Societies	None	Minimum 5*s*.	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society	Arthur Quayle, 409 Lord Street, Southport	135	None	7*s*. 6*d*.	Proceedings, annually.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham	174	1*l*. 1*s*. and 10*s*. 6*d*.	31*s*. 6*d*. and 21*s*.	Transactions of Institution of Mining Engineers, monthly.
Tyneside Geographical Society, 1887	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne. Herbert Shaw, B.A., F.R.G.S.	1,000	None	10*s*.	Journal, annually.

Vale of Derwent Naturalists' Field Club, 1887	W. Johnson, Byer Moor, Burnopfield, Co. Durham	122	None	2s. 6d.	Transactions, occasionally.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	80	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	260	10s.	10s.	Transactions, biennially.
Worcestershire Naturalists' Club, 1847	Victoria Institute, Worcester. William H. Edwards	107	10s.	5s.	Transactions, annually.
Yorkshire Geological Society, 1837	J. H. Howarth, F.G.S., Somerley, Rawson Avenue, Halifax	214	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	The Museum, Hull. T. Sheppard, F.G.S.	478 and 3,368 Associates	None	10s. 6d.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Museum, York. Dr. Tempest Anderson and O. E. Elmhirst.	480	None	2l.	Report, annually.

Associated Societies.

Bakewell Naturalists' Club, 1896	W. Storrs Fox, M.A., F.Z.S., St. Anselm's, Bakewell	55	None	5s. and 2s. 6d.	—
Balham and District Antiquarian and Natural History Society, 1897	A. L. Barron, Clophill, Wallington, Surrey	61	None	5s.	Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientfic Association, 1876	Cambridge Hall, Strand, Barrow. W. L. Page, 5 Cavendish Street	335	None	5s. and 2s. 6d.	Report and Proceedings, &c., annually.
Battersea Field Club, 1894	Public Library, Lavender Hill, Battersea, S.W. Everard J. Davies	50	None	3s. 6d.	—
Bournemouth and District Society of Natural Science, 1903	Dr. J. R. L. Dixon, 2 Wootton Gardens, Bournemouth	220	None	5s.	Report, annually.
Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, Wilton Street, Bradford	75	1s.	4s.	—
Catford and District Natural History Society, 1897	W. H. Griffin, 6 Rutland Park, Catford, S.E.	80	1s.	3s.	—
Dover Sciences Society, 1879	Percy Moring, 23 Randolph Gardens, Dover	65	None	6s.	Reports, annually; leaflets, occasionally.
Dunfermline Naturalists' Society, 1902	Robert Somerville, B.Sc., 82 James Street, Dunfermline	188	None	5s.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, 133 The Grove, Ealing, W.	125	None	10s. and 2s. 6d.	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. Dr. G. A. Grierson	102	None	4s.	—
Hampstead Scientific Society, 1899	C. O. Bartrum, B.Sc., 12 Heath Mansions, Heath Street, Hampstead, N.W.	309	None	Minimum 5s.	Report and Proceedings, annually.
Haslemere Microscope and Natural History Society, 1888	F. A. Oldaker, The Red House, Haslemere	86	None	Minimum 2s.	Report, annually; Science Papers, occasionally.

Associated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Hastings and St. Leonards Natural History Society, 1893	Corporation Museum, Brassey Institute, Hastings. W. Ruskin Butterfield	320	1s.	2s. 6d.	'Hastings and East Sussex Naturalist,' half-yearly.
Inverness Scientific Society and Field Club, 1875	W. J. Watson, Royal Academy, Inverness	187	None	5s.	Transactions, occasionally.
Ipswich and District Field Club, 1903	Charles B. White, 19 Salisbury Road, Ipswich	140	None	1s.	—
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. H. R. Sweeting, M.A.	140	None	5s.	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Norman Treliving, 51 Lofthouse Place, Leeds	71	None	6s.	Transactions, occasionally.
Lewisham Antiquarian Society, 1885	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S.E.	100	None	5s.	Transactions, occasionally.
Liverpool Microscopical Society, 1866	Royal Institution, Liverpool. W. T. Haydon	65	10s. 6d.	10s. 6d.	Report, annually.
Liverpool Science Students' Association, 1881	Royal Institution, Liverpool. H. W. Greenwood	48	2s. 6d.	5s.	—
London: City of London Entomological and Natural History Society, 1858	The London Institution, Finsbury Circus, E.C. Edward Harris	78	2s. 6d.	7s. 6d.	Transactions, annually.
London: North London Natural History Society, 1892	R. W. Robbins, Tonah, Falmouth Avenue, Hale End, Chingford	103	2s. 6d.	5s. and 2s. 6d.	Report, annually.
London: South London Entomological and Natural History Society, 1872	Hibernia Chambers, London Bridge, S.E. Stanley Edwards, F.L.S.	170	2s. 6d.	7s. 6d.	Proceedings, annually.
Maidstone and Mid-Kent Natural History Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	116	None	10s. and 5s.	Report, occasionally.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes and Frederick Emley	2,800	None	1l. 1s.	—
Penzance Natural History and Antiquarian Society, 1839	Public Buildings, Penzance. J. B. Cornish	50	None	10s. 6d.	Transactions, occasionally.
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. W. Hy. Heathcote	598	None	5s.	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	The Museum, Scarborough. Herbert King, M.Sc.	90	None	1l. and 10s.	Report, annually.
School Nature Study Union, 1903	Miss M. R. N. Holmer, Bedford College, York Place, London, W.	500	None	2s.	'School Nature Study,' three times a year; leaflets, occasionally.
Scottish Microscopical Society, 1888	Philosophical Institution, 4 Queen Street, Edinburgh. Dr. W. G. Robertson	60	None	10s. 6d.	Proceedings, annually.
Southport Society of Natural Science, 1890	W. T. Barnett, 52 Talbot Street, Southport	276	None	5s.	Report, annually.
Teign Naturalists' Field Club, 1858	P. F. S. Amery, Druid, Ashburton, Devon	120	None	2s. 6d.	Report, annually.
Torquay Natural History Society, 1844	Alex. Somervail, The Museum, Torquay	209	10s. 6d.	1l. 1s.	—
Tunbridge Wells Natural History and Philosophical Society, 1884	R. R. Hutchinson, 28 Princes Street, Tunbridge Wells	157	None	10s. 6d., 5s., and 3s. 6d.	Report, annually.
Warrington Field Club, 1884	Alf. J. Jolley, 16 Arpley Street, Warrington	53	None	2s.	—
Watford Camera Club, 1902	W. R. Gunton, 139 High Street, Watford	75	None	10s. and 5s.	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1907.

, This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

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Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Dr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Professors W. E. AYRTON, J. PERRY, W. G. ADAMS, *and* G. CAREY FOSTER, Sir OLIVER J. LODGE, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professors A. SCHUSTER, J. A. FLEMING, *and* J. J. THOMSON, Dr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. J. RENNIE, Principal E. H. GRIFFITHS, Sir A. W. RÜCKER, Professor H. L. CALLENDAR, *and* Mr. GEORGE MATTHEY.

THE main work during the year has been the completion of the work with the ampere balance. The general results are referred to in some detail below. The final measurements confirm the opinion expressed in last year's Report that an accuracy of a few parts in 100,000 might be reached. It appears that the result is probably accurate to 1 in 50,000.

Interim reports on the ampere balance, indicating the progress of construction, adjustment, and use of the instrument, have been submitted to the Association since 1904.

The Committee are now pleased to report that the balance continues to give complete satisfaction. During the past year it has been much used for determining the e.m.f. of the Normal Weston Cadmium cell and the electrochemical equivalent of silver. A description of the instrument, its construction and adjustment, and the results obtained with it in the cadmium cell determinations, has been prepared and submitted to the Royal Society for publication in its 'Transactions,' by Professor Ayrton, Mr. Mather, and Mr. F. E. Smith. An account of the work on the electrochemical equivalent of silver is well advanced and will be published shortly.

In all some 71 observations have been made on a certain cadmium cell (No. 2), using both sets of coils on the balance, and 13 observations in which one or other of the two sets was employed. The agreement between the individual results obtained with the two sets of coils is remarkable, the average difference from the mean amounting only to 6 parts in a million. The whole series of observations extended over a period of nineteen months (September 1905 to April 1907), and during that time the coils of the balance were reset five times. No determination made has been omitted, except those in which the observations were of such a nature that a decision to disregard the result was arrived at before its computation. Such occasions were rare.

Of the 71 observations made

7	are within	1 in a million of the mean
14	,, ,,	2 ,, ,, ,, ,,
28	,, ,,	5 ,, ,, ,, ,,
53	,, ,,	10 ,, ,, ,, ,,
66	,, ,,	15 ,, ,, ,, ,,
70	,, ,,	20 ,, ,, ,, ,,

Only one determination out of the whole 71, and this one of the earliest, differs from the mean by so much as 1 part in 59,000.

The above facts constitute important evidence of constancy in both balance and cell. In fact, both current-weigher and cell proved to be much more constant and reliable than the standard resistance, although the latter was very carefully made and annealed with a view to ensuring permanency.

Expressed in terms of the international ohm as realised at the National Physical Laboratory, and of the ampere as given by the new current-weigher, we find that the value of $C \times R$ for the normal Weston cadmium cell is $1{\cdot}01830_5$ at 17° C.

This assumes that the value of g at Teddington is 981·19, a number probably correct to within 3 part in 100,000. An uncertainty of this amount in g introduces a possible error of $1\frac{1}{2}$ part in 100,000 in the value of the ampere, and, as all other probable errors are smaller in magnitude, it is important that a more accurate determination of g be made.

To realise the volt with an accuracy approaching that of the ampere, as now known, it is necessary that an absolute determination of resistance of corresponding precision be undertaken. Through the kindness of the Drapers' Company of London it is hoped that such a determination by means of a Lorenz apparatus may be completed at the National Physical Laboratory before the end of next year. At the present time the uncertainty in the absolute value of the international ohm approximates to 4 in 10,000.

From the above value of $C \times R$ for the cadmium cell, together with the ratio of Clark to cadmium, viz.,

$$\frac{\text{Clark at } 15^\circ \text{ C.}}{\text{Cadmium at } 17^\circ \text{ C.}} = 1{\cdot}406_6,$$

the e.m.f. of the Clark cell at 15° C. becomes $1{\cdot}432_3$.

The Committee recognise very fully the skill and devotion of Mr. Mather and Mr. Smith, on whom the work of carrying out the experiments has fallen, and have invited these gentlemen to become members of the Committee.

Papers by Mr. F. E. Smith, of the National Physical Laboratory, dealing with the use of the silver voltameter and the preparation of the Weston cadmium cell, are nearly ready for publication.

Some preliminary work has also been done on the design for the Lorenz apparatus, the funds for which are being found by the Drapers' Company. The proposed design embodies new features of importance.

With regard to the proposed Conference on Electric Units, further consideration led to the conclusion that a year's delay was desirable, and in consequence the meeting was postponed from October 1906 to

October 1907. With a view to a preliminary agreement on the matters to be raised, correspondence has passed during the year between the Secretary, acting as Director of the National Physical Laboratory, and the heads of standardising laboratories in other countries. The Conference will probably deal with the drawing up of an International Convention relative to Electric Units, which should include the draft of a form of law which might be adopted generally in the various countries represented, and the consideration of the steps necessary to secure uniformity in the carrying out of the laws in different countries, and to arrange for determinations necessary for this purpose.

The necessary invitations for the Conference are being issued by his Majesty's Government.

To secure uniformity in carrying out the law it will be necessary that specifications for constructing and using a mercury unit of resistance, for setting up and working a silver voltameter, and for preparing a standard cell, be approved either by the Conference itself or by some body nominated by the Conference for this purpose.

With a view to aiding discussion, very detailed specifications dealing with the voltameter and the cell have been prepared by the National Physical Laboratory and issued to other standardising institutions. These are printed in Appendices II. and III.

It is not suggested that the final specifications need be so full or so detailed, but it was thought well that all information necessary to assist in criticising the results should be included.

The work on the silver voltameter and Weston cell still continues and, in view of the deliberations of the Conference, it is probable that further expenditure will be required. The accounts show that a balance of 10*s*. 8*d*. remains from the grant of 50*l*. made last year. The grant has been spent on the purchase of material and appliances for the research.

In view of the importance of bringing the work of re-determining the values of the fundamental units to a satisfactory conclusion, the Committee recommend that they be reappointed, with a grant of 50*l*., and with the addition of the names of Mr. A. P. Trotter, Mr. T. Mather, F.R.S., and Mr. F. E. Smith; that Lord Rayleigh be Chairman and Dr. Glazebrook Secretary.

APPENDIX I.

Notes on the Present Condition of the Work on Electric Units at the National Physical Laboratory. By F. E. SMITH.

(From the National Physical Laboratory.)

1. *The Ohm.*—(a) *Absolute Unit.*—The value of a resistance in absolute measure is still subject to considerable uncertainty; the most satisfactory value is obtained from the mean observed ratio of the International Ohm to the absolute ohm.[1]

A provisional design has been prepared for the Lorenz apparatus which the Drapers' Company are kindly presenting to the National Physical Laboratory, and experiments to test the more important features

[1] See table in the *Brit. Assoc. Rep.* for 1892.

of the design are in progress. It is hoped to realise the ohm in absolute measure to 1 part in 100,000. The experience gained in the construction of many of the fittings of the ampere balance will greatly facilitate the work.

(b) *International Unit.*—Further comparisons of some of the mercury standards of the National Physical Laboratory were made in October and November 1906. There appears to have been no change in any of the tubes which affects the resistance of the contained mercury columns by as much as 1 part in 100,000. The following table gives the observed differences in 1903 (the year of their construction) and in October and November 1906.

Mercury Standards Compared.	Observed Difference in Int. Ohms in 1903.	Observed Difference in Int. Ohms in 1906.
M – P	$0{\cdot}00069_4$	$0{\cdot}00068_5$
M – T	88_6	89_2
M – U	94_7	95_3
M – V	$-\ 29_8$	$-\ 30_1$
M – X	01_3	02_3

2. *The Ampere.* (a) *Absolute Measure.*—When the ampere balance was designed it was hoped by means of it to measure a current in absolute value to 1 part in 10,000, but it will be seen from the report on the balance that the evaluation of a current of nominal value 1 ampere is subject to an error which appears to be not greater than 1 part in 50,000.

(b) *International Unit of Current.*—The International Conference on Electric Units at Charlottenburg (1905) reaffirmed the definition of the International ampere in terms of the deposit of silver in a silver voltameter or coulometer, but expressed the opinion that the information before it was insufficient to enable it to propose any alteration in the formerly accepted value for the ampere, or to lay down exact directions in respect to the silver voltameter.

The Rayleigh type of voltameter has been used in a large number of investigations, but the researches of Rodger and Watson, Richards, Kahle, and others have shown that this voltameter as generally employed gives results which may vary as much as 1 part in 1,000.

In the research at the National Physical Laboratory a reproducible type of voltameter was sought, but after making a large number of observations on various forms it was found that, subject to certain easily attained conditions, all the forms give identical results to 1 part in 100,000. As the Rayleigh type is the simplest to erect and produces the least variation in the current strength, it is proposed that this form be specified. The conclusions arrived at in the research differ appreciably from those of most other observers, and attempts have been made experimentally to reproduce the conditions under which they worked. In part we have been successful, but there are still anomalous results for which we can at present offer no explanation.

It is certain, however, though the complete chemistry of the silver voltameter or coulometer is unknown, that a reproducible type can be specified, and that the International ampere can be defined in terms of the deposit of silver with very great accuracy, certainly to 1 part in 100,000.

The Standard Cell.—For the past five years experiments have been made at the National Physical Laboratory on Clark and on Weston cadmium cells, and two years ago a provisional specification of the

cadmium cell was published. It is gratifying to know that the specification proved of value, for in 1906 fifty-one cadmium cells were submitted for test at the National Physical Laboratory, and all of these were prepared on the lines of the specification. The cells were intended for commercial use, and they were packed with small crystals of cadmium sulphate to be more portable; also we have reason to believe that in some cases the mercurous sulphate had not been properly washed, and in other cases the solution of cadmium sulphate was slightly acid. Nevertheless the e.m.f. of these cells agreed with the N.P.L. cells to about 2 parts in 10,000, the N.P.L. cells having the lower voltage. Standards more carefully set up have been submitted by two observers for comparison with the N.P.L. cells in accordance with the offer made in the 'British Association Report,' 1905. The cells prepared by one of these observers—Mr. Tinsley of Beckenham—differed from the N.P.L. cells by about 0·1 millivolt, or 1 part in 10,000. Mr. Mather also submitted a number of cells, and these had approximately the same mean e.m.f. as those from Mr. Tinsley. The N.P.L. cells were the lower in voltage, and freshly prepared cells agree with old ones.[1]

In May 1907 twelve Weston cadmium cells set up by Dr. Wolff at the National Bureau of Standards, Washington, were compared with a number of the cells of the National Physical Laboratory, and a mean difference of 3 parts in 1,000,000 was measured. Dr. Wolff's cells were, we believe, set up quite independently of the N.P.L. specification, which makes this remarkable agreement all the more gratifying.

APPENDIX II.

Specification for the Practical Application of the Definition of the International Ampere.

(From the National Physical Laboratory.)

In the following specification the term silver voltameter (or coulometer) means the arrangement of apparatus by means of which an electric current is passed through a solution of silver nitrate in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time-average of the current, or, if the current has been kept constant, the current itself, can be deduced.

In employing the silver voltameter to measure currents of *about 1 ampere* the following arrangements should be adopted: The kathode on which the silver is to be deposited should take the form of a platinum bowl about 10 centimetres in diameter and 7 centimetres in depth. The mass of the bowl is conveniently about 80 grams.

The anode should be a plate or disc of pure silver coated with a deposit of electrolytic silver, the mass of the latter being about 50 per cent. greater than the mass of silver to be deposited on the kathode. The plate or disc of silver should be of about 6 centimetres edge (or diameter) and 3 or 4 millimetres in thickness. Its total area will thus approximate to 60 square centimetres. The anode should be supported horizontally in the liquid near the top of the solution by a silver rod riveted through its

[1] In Mr. Mather's cells electrolytic mercurous sulphate was used; in Mr. Tinsley's cells the mercurous sulphate was prepared by the chemical precipitation method.

centre. To prevent the disintegrated silver which is formed on the anode from falling upon the kathode the anode should be inserted into a cup of filter paper separately supported.

The liquid should consist of a neutral solution of pure silver nitrate, containing about fifteen parts by weight of the nitrate to eighty-five parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current some resistance besides that of the voltameter should be inserted in the circuit. If the value of the current is desired and the measurement is one of high precision, this external resistance should be from 50 to 100 ohms; in other cases the resistance should not be less than 10 ohms.

Method of making a Measurement.

1. *The Solution.*—The silver nitrate should be purchased as pure and recrystallised twice; the recrystallisation is preferably done by evaporating a saturated solution in a flask over a water-bath. The mother liquor should be drained away and the crystals dissolved in pure freshly distilled water. Prolonged contact of the crystals or of the solution with impure air must be avoided. The solution should be neutral to sensitive litmus-paper.

If the silver nitrate is recovered from much used or contaminated solutions, or from an acid solution, the recovered salt should be fused (preferably in an electric oven) and afterwards dissolved, and the solution filtered before the recrystallisation processes; otherwise it may be necessary to recrystallise more than twice.

During electrolysis in the voltameter herein specified the silver nitrate solution does not change in composition *as a result of the electrolysis* by an amount which is detectable by any tried means, but, owing to the presence of impurities in the atmosphere, the solution should not be used more than once if great accuracy is desired.

2. *The Anode.*—The anode should be prepared by cleaning the silver plate or disc with sandpaper or a scratch-brush. It should be washed with distilled water and supported so as to form the *kathode* of a silver voltameter. The anode of this latter should be a silver bowl or a platinum bowl coated with silver, and the liquid should be a 15 per cent. solution of silver nitrate in water; this solution need not be specially pure. If the anode bowl is of platinum coated with silver and of the dimensions already specified, it is convenient to employ about 350 cubic centimetres of the solution and support the silver plate or disc horizontally in the liquid near the top of the solution. A convenient current for depositing silver on the plate is 0·3 ampere. The plate is washed with distilled water and dried in an electric oven.

The cup of filter-paper should be about 5 centimetres deep and of a diameter a little greater than that of the silver plate. It is made by folding a large filter-paper (such as Schleicher and Schull No. 595, 24 cm. diameter) over a glass cylinder (such as a bottle) of appropriate diameter and securing the upper portions of the folds of the paper with sealing wax or with platinum wire. The cylinder is removed and that portion of the paper which is above the seals is cut away. The upper parts of the internal folds are also secured with sealing wax or with platinum wire.

3. *The Kathode.*—The platinum bowl should be cleaned with a strong

solution of sodium hydrate, followed by washings with water, strong nitric acid, and distilled water. It is then made the *anode* of a silver voltameter, the liquid being a 15 per cent. solution of silver nitrate (an impure solution serves) having a volume of about 350 cubic centimetres. The kathode should be a clean silver plate supported near the top of the solution. With a current of about 1 ampere the circuit should be completed for ten minutes at least, after which the kathode and liquid are removed from the bowl. The bowl is washed with water and afterwards cleaned with strong nitric acid; washings with distilled water, strong nitric acid, and distilled water follow in the order named, and the bowl is dried in an electric oven at about a temperature of 160° C. It is removed to a desiccator and when thoroughly cool is weighed. A bowl of similar size and of approximately the same mass is convenient as a counterpoise.

4. *The Circuit.*—The platinum bowl is placed in position in the intended circuit and 300 cubic centimetres of the solution of silver nitrate are placed in it. The anode is placed inside the filter-paper cup and the latter suspended by platinum wires, which are insulated from the anode and from the rest of the circuit. The anode and filter-paper cup are supported so that the silver plate or disc is covered by the solution; the connections to the remainder of the circuit are then made. Contact is made at a key and the time noted. The current is allowed to pass for an interval depending on the precision desired, and the time of breaking contact must be observed. For measurements of high precision from 7 to 10 grams of silver should be deposited. During the passage of the current the voltameter should be covered over, to exclude light.

5. *Deposit of Silver.*—The solution is removed from the bowl and the deposit rinsed with about 100 cubic centimetres of distilled water. The washing water is poured into a clean glass crystallising-dish and the operation of washing is repeated three times. The bowl is then nearly filled with distilled water and left for at least three hours; it is rinsed three times, the last of these washing waters remaining in the bowl for ten minutes. This should give no milkiness when added to a neutral solution of sodium chloride in water. The bowl is dried in an electric oven at a temperature of about 160° C.

If any loose silver is observed in the solution outside of the filter-paper cup, or in the washing waters, these liquids must be filtered, the filter-paper dried, and the loose silver added to the bowl before drying the deposit. The bowl is cooled in a desiccator and weighed again. The gain in mass gives the silver deposited.

6. *Calculation.*—To find the current in amperes this mass, expressed in grams, must be divided by the number of seconds during which the current has been passed and by 0·001118. The result will be the time-average of the current, if during the interval the current has varied.

In determining the constant of an instrument by this method the current should be kept as uniform as possible, and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated from the voltameter results, corresponds with this reading.

Notes on Observations.—If this specification is carefully followed the mass of silver deposited for the passage of one coulomb through the voltameter is constant within the limits of the errors of measurements of the highest precision. It is certainly constant to 1 part in 100,000.

The specification is possibly too rigorous for many practical needs, and for such a simplification is possible. The solution of silver nitrate may be prepared from purchased silver nitrate, provided it is free from acid. The anode may be a plate of pure silver without electrolytic silver deposited thereon. The remainder of the specification must be followed.

Effect of Pressure.—The observations may be made at any ordinary atmospheric pressure, or exceptionally low pressures, as the mass of silver deposited when the silver voltameter is under a pressure of 76 centimetres of mercury is the same as when under any lower pressure to 2 centimetres of mercury, and possibly without these limits.

Effect of Temperature.—This specification is based on observations at or about a temperature of 17° C. Observations at other temperatures have been made and are being continued; if there is a temperature coefficient to the silver voltameter it is exceedingly small.

This specification is based on the results of a large number of measurements made at the National Physical Laboratory.

APPENDIX III.

Preparation of the Weston (Cadmium) Standard Cell.

(From the National Physical Laboratory.)

Definition of the Cell.—The cell has mercury for its positive electrode and an amalgam of cadmium, consisting of 12½ parts by weight of cadmium to 87½ parts of mercury, for its negative electrode. The electrolyte consists of a saturated solution of cadmium sulphate, and solid cadmium sulphate is contained within the cell. A paste consisting of solid mercurous sulphate, mercury, and cadmium sulphate rests on the positive electrode.

Preparation of the Materials.

1. *Mercury.*—Commercially pure mercury should be squeezed through wash-leather and passed in the finely divided condition in which it emerges through dilute nitric acid (1 part of acid to 6 parts of water) and mercurous nitrate solution, and afterwards through distilled water. These liquids are conveniently contained in long glass tubes. The mercury is then distilled twice *in vacuo*. Mercury suspected of any abnormal contamination should not be employed.

2. *Cadmium Amalgam.*—A current is passed from a thick rod of pure commercial cadmium to distilled mercury, the intervening liquid being cadmium sulphate solution rendered slightly acid with a few drops of sulphuric acid. The kathode is weighed before electrolysis commences, and again afterwards; the percentage of cadmium in the amalgam is then calculated. More than the requisite amount of cadmium should be deposited and the percentage reduced to 12½ by the addition of mercury. To prevent the anode slime having access to the kathode the anode should be contained in a filter-paper cup, as in the Rayleigh form of silver voltameter. Contact with the kathode is made by a platinum wire sealed into a glass tube, the wire being thus protected from direct contact with the cadmium sulphate solution. An approximate estimate of the quantity of cadmium deposited is obtained from the readings of an ammeter placed in the circuit. The amalgam, with very dilute sulphuric acid flooding its

surface, is melted over a water-bath and stirred to ensure homogeneity. It is then ready for use.

3. *Cadmium Sulphate.*—Procure commercially pure cadmium sulphate, $CdSO_4 . 8/3\ H_2O$. Powder in a mortar and dissolve in distilled water until a saturated solution results: filter the solution through a fine-grained filter-paper until it is quite clear. The liquid should then be placed in a large crystallising dish and slowly evaporated at a temperature of about 35° C., when, provided that dust is excluded, many transparent crystals of $CdSO_4 . 8/3\ H_2O$ will result. In this way about five sixths of the solution may be evaporated (the mother liquor may be used for a preliminary washing of the mercurous sulphate, the manufacture of which is described hereafter). The recrystallised cadmium sulphate should be washed with successive small quantities of distilled water, until after standing for ten minutes no trace of acidity can be detected in it with sensitive congo-red paper: the crystals, still moist, are transferred to a stock bottle. To prepare the saturated solution the crystals are crushed in a mortar and agitated with distilled water The latter may be warmed to 35° C.

4. *Mercurous Sulphate.*—Add 15 cubic centimetres of pure strong nitric acid to 100 grams of pure mercury contained in a crystallising dish, and place on one side until the action is over, or nearly over. Transfer the mercurous nitrate thus formed, together with the excess of mercury, to a beaker containing about 200 cubic centimetres of dilute nitric acid (1 of acid to 40 of water by volume); a clear solution should result. Prepare about 1 litre of dilute sulphuric acid (1 of acid to 3 of water by volume), and while the mixture is hot add the acid mercurous nitrate solution to it. The solution should be added as a *very* fine stream from the narrow orifice of a pipette and the mixture violently agitated during the mixing. Mercurous sulphate is precipitated and rapidly settles to the bottom of the vessel when the stirring ceases. Decant the hot clear liquid and wash the precipitate twice by decantation with dilute sulphuric acid (1 of acid to 6 of water by volume). The precipitate should then be filtered. (A small Buchener filter funnel and a filter flask is very convenient for this latter operation.) Wash the precipitate three times with the dilute sulphuric acid (1 to 6), and afterwards wash six or seven times with saturated cadmium sulphate solution to remove the acid. After each washing the liquid should be removed as completely as possible by the filter pump. When these operations are complete, the mercurous sulphate is flooded with saturated cadmium sulphate solution and left for one hour; the solution is then tested with congo-red paper. In general no acid will be detected, and the mercurous sulphate is ready for use. It is placed in a stock bottle together with some saturated cadmium sulphate solution, and should be kept in the dark. If acid is detected, the washing must be continued. When the cells are required for observations of the highest precision, the apparently neutral mercurous sulphate should not be immediately used. It is placed in a bottle with saturated cadmium sulphate solution, and at the end of one week the latter is tested for acidity. The sulphate is given another washing with the solution, and may then be used if only a trace of acid is detected.

One of the following methods of preparation may, if desired, be substituted for the foregoing :—

(1) *Electrolytic Method.*—This preparation is conducted in a darkened room. Pure distilled mercury forms the anode and platinum foil the

kathode, the electrolyte being dilute sulphuric acid (1 volume of acid to 5 volumes of water). The mercury is placed in the bottom of a large flat-based beaker and about twenty times its volume of the dilute acid is added. Contact with the mercury is made by a platinum wire passing through a glass tube, and the kathode is suspended in the upper portion of the liquid. During electrolysis the electrolyte must be continually stirred, an L-shaped glass stirrer being very efficient, the foot of the L moving close to the surface of the mercury. A convenient current density is 0·01 ampere per square centimetre of anode surface. The mercurous sulphate so prepared is filtered and the greater part of the mercury removed; it is then washed with dilute sulphuric acid and saturated cadmium sulphate solution in a manner already described for the previous preparation.

(2) *By means of Fuming Sulphuric Acid.*—Place distilled mercury in a crystallising dish so as just to cover the bottom. Add sufficient fuming sulphuric acid to flood the surface of the mercury to a depth of about 2 millimetres. Cover with a clock glass and place on one side for 48 hours. Mercurous sulphate is formed and appears in the crystalline form. Carefully add the salt to hot dilute sulphuric acid (1 to 6) and well agitate. Decant the hot liquid. If any caked masses of the sulphate are left, these should be rejected or crushed in an agate mortar. Wash three times by decantation with hot dilute sulphuric acid, and afterwards filter and wash with saturated cadmium sulphate solution in the manner already described. Set aside with cadmium sulphate solution for one week at least, test for acidity, and wash as described for the first preparation.

The Mercurous Sulphate Paste.—The mercurous sulphate is mixed with about one-fourth its volume of powdered recrystallised cadmium sulphate, and about one-tenth its volume of pure mercury. (When the electrolytic sulphate is used, or that prepared with fuming sulphuric acid, no mercury need be added.) To the mixture of mercurous sulphate, cadmium sulphate, and mercury, sufficient saturated cadmium sulphate solution is added, so that when well mixed the whole forms a thin paste.

Setting up the Cell.—That type of H-form of cell which may be hermetically sealed is the most convenient; if the lower end of each limb is slightly constricted, the contents of the cell are less liable to be disturbed. The platinum wires inside the glass vessel are amalgamated by passing an electric current from a platinum wire anode through an acid solution of mercurous nitrate to each of the wires in turn as a kathode. The vessel is washed out twice with dilute nitric acid, several times with water, and finally with distilled water; it is dried in an oven. A small pipette is used for the introduction of the amalgam, and a small thistle funnel for the insertion of the paste and crystals. The main stock of amalgam is flooded with very dilute sulphuric acid, and it is melted over a water-bath; a little of it is introduced into one of the limbs of the H-vessel. After the amalgam has solidified, this limb must be washed out several times with distilled water, care being taken to avoid wetting the interior of the other limb. A little distilled water is added and the amalgam is melted by immersing the limbs of the H-vessel in hot water. After the solidification of the amalgam, it is washed once more with distilled water. Into the other limb sufficient mercury is introduced to cover the amalgamated platinum wire; then the paste is added, care being taken not to smear the sides of the vessel. Finally, powdered crystals of cadmium sulphate are introduced into each limb, and saturated

cadmium sulphate solution is added. The cell may be immediately sealed with the aid of a blowpipe, but the contents must not be abnormally heated thereby. The cadmium amalgam introduced should cover the amalgamated platinum wire; the depth of the paste should be from 0·5 cm. to 1·0 cm., and the depth of the layer of crystals about 0·5 cm. twenty-four hours after the cell has been set up it may be used. Its electromotive force at 15° C. is $1{\cdot}018_5$ volt. The electromotive force at any other temperature may be obtained from the formula given by the Phys. Techn. Reichsanstalt, viz.,

$$E_t = E_{20} - 0{\cdot}000038(t-20) - 0{\cdot}00000065(t-20)^2,$$

or from the formula obtained at the National Physical Laboratory,

$$E_t = E_{17} - 0{\cdot}000034_5(t-17) - 0{\cdot}00000066(t-17)^2.$$

This specification is based on observations made at the National Physical Laboratory.

Seismological Investigations.—Twelfth Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Dr. J. MILNE (*Secretary*), Lord KELVIN, Dr. T. G. BONNEY, Mr. C. VERNON BOYS, Sir GEORGE DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Professor J. W. JUDD, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, *and* Mr. NELSON RICHARDSON. (*Drawn up by the Secretary.*)

[PLATE I.]

CONTENTS.

I. *General Notes on Stations and Registers.*

THE registers issued during the past year are Circulars Nos. 14 and 15. They refer to Shide, Kew, Bidston, Edinburgh, Paisley, Victoria (B.C.), Alipore, Bombay, Kodaikânal, Batavia, Cairo, San Fernando, Cape of Good Hope, Ponta Delgada (Azores), Toronto, Pilar, Beirût, Baltimore, Trinidad, Honolulu, Perth (W.A.), Christchurch (New Zealand), Mauritius.

Records have not yet been received from Melbourne, Sydney, and Arequipa; while registers from Wellington, Philadelphia, and Mexico should be brought up to date. The Seismological Committee of the British Association would be greatly indebted to the Directors of observatories at these places if they would kindly forward copies of their observations.

Some time ago a Milne seismograph, which records on a band

2 inches wide, was sent to F. Bareda Y. Asma, Esq., Lima, Peru. This was for the use of the Geographical Society. This year a two-component instrument, recording on a cylinder moving at the rate of 25 cm. per hour, was forwarded to W. G. Davis, Esq., Director of the Meteorological Department, Buenos Ayres. Its number is 49. Two instruments are being constructed for the Public Works Department, Cairo. The intention is to instal one of them at Khartoum and the other near the Victoria Nyanza. We understand that an instrument has been ordered for the Government of South Australia.

Mr. Richard Cooke, The Croft, Detling, Maidstone, has again kindly sent 1*l.* 1*s.* for the support of seismological research.

At a Committee meeting held on February 21, Professor J. W. Judd expressed a strong wish to retire from the office of chairman, which office he had held for nine years. The announcement was naturally received with regret, and a vote of thanks was accorded to Professor Judd for his valuable services. Professor H. H. Turner has kindly consented to take over the vacant position.

The office accommodation at Shide has been increased, and has been seen by the President and several members of your Committee. Mr. H. C. O'Neill joined me as an assistant on March 11, since which time he has been daily attending to the instruments and the regular routine work. I also receive assistance from Messrs. S. Hirota and J. H. Burgess, who, as you are aware, have worked at this observatory since its establishment.

Correspondence, which is frequently of a descriptive nature and requires photographic and other illustrations, has naturally increased with the growth in number of stations and the increasing interest in earthquake phenomena. Material has been supplied to the Committee connected with the Carnegie Institute investigating the San Francisco earthquake, to the Central Bureau of the International Seismological Association, and to many others.

II. *The Situations of Stations.*

Continued from 'British Association Reports,' 1905, p. 84, and 1906, p. 93.

Pilar, Argentina.

On January 20, 1905, the seismograph was dismounted in Cordoba and removed to Pilar, our new magnetic station, lat. 31° 40′ and 4h. 15·4m. W. of Greenwich. A special building was erected for the seismograph and Mascart's electrometer. The building is of brick, with cemented floors and ventilation coming through the floor and passing through the roof, with two windows on opposite sides of the building. The pier on which the seismograph rests is built of masonry, with its foundations extending to a depth of 1·5 metre below the floor. The ground is compact alluvial deposit. The building is situated about 100 metres from the Rio Segundo, that is, the river Segundo. In summer there is frequently a large volume of water, but in winter the river is practically dry.

The instrument was installed on February 1, 1905, but the masonry was not considered sufficiently settled to allow of trustworthy registers from the instrument till the end of the month, so that the records of 1905 begin on March 1. The photographic record, however, shows no well-defined movement during the month of February. The period of the boom oscillations was kept constant from the month of February till June 22, at 17 seconds, the same as formerly used in Cordoba, giving a sensibility of 0″·56. On November 2 this was increased to 16 seconds, with a sensibility of 0″·50 to one millimetre of displacement of the outer end of the boom.

W. G. Davis, *Director.*

Colombo, Ceylon (Observatory at the Technical College).

Lat. 6° 54′ N.; long. 79° 51′ E.; alt. 13 feet above mean sea-level.

Foundation.—A brick-in-cement pier built on a cement-concrete base rising from a bed of laterite.

Topographical Situation.—The Observatory is situated on low ground, quite close to a canal, about 50 feet from the bank of it. There is a lake about 150 yards away towards the south-west, with which the canal communicates direct. The sea is about a mile distant (south-west) from the Observatory. The canal above mentioned is on the north of the Observatory.

Geological Structure.—The ground surrounding the Observatory to a considerable distance is alluvium with outcropping laterite.

Rating.—The rating of the time-keeper attached to the instrument is done by comparison with the chronometer of the Master Attendant, Colombo Harbour, at intervals of two to three days, by means of a portable time-keeper carried backwards and forwards in a locked box. Periodic time of instrument varied between 18 seconds and 15 seconds. During the period August to December the periodic time did not fall below 17 seconds, and for the months of September and October the periodic time was nearly 18 seconds.

E. HUMAN, *Superintendent.*

III. *Photographic Record-receivers.*

If two similar and similarly adjusted seismographs are installed on sites which are geologically and topographically different it is to be expected that the records they yield will show certain differences. If, for example, we compare the seismograms obtained at a station on rock with one on alluvium we find that at the former, within a given period, more records have been obtained, and earlier times of commencement, than at the latter.[1] The probable explanation of this is that thick beds of alluvium, in consequence of their non-elastic nature, do not transmit the waves of small amplitude which constitute small earthquakes and the preliminary tremors of larger disturbances.

Another condition on which the recording of very minute waves is dependent, and which does not hitherto appear to have been recognised, is the speed of the film on which the record is received.

In connection with the Milne horizontal pendulums adopted by the British Association, two types of recording surfaces are now employed. In one the photographic film moves beneath a slit about 0·25 mm. in width at the rate of 60 mm. per hour. In the other the photographic surface passes beneath a similar slit at a little over four times that rate.[2] In the first type of receiver the paper as it passes the slit is exposed to light for fifteen seconds, whilst in the second the exposure is between three and four seconds. Experiment shows that the line obtained from the long exposure may be double the breadth of that from the short exposure. From this it would seem that minute tremors with a short period which would show as deviations of the narrow line might be eclipsed if the same became broadened by halation. This, however, would not be the case if the tremors had a very long period.

This probably explains the observation that earlier commencements are more frequently noticed on a rapidly moving surface than on one which moves more slowly. For example, for the year ending June 1906, for a series of sixty-one disturbances, a pendulum, at Shide recording on a quickly moving surface was on forty occasions from one to six minutes in advance

[1] See *Brit. Assoc. Rep.*, 1902, p. 74, and 1903, p. 82. [2] *Ibid.*, 1904.

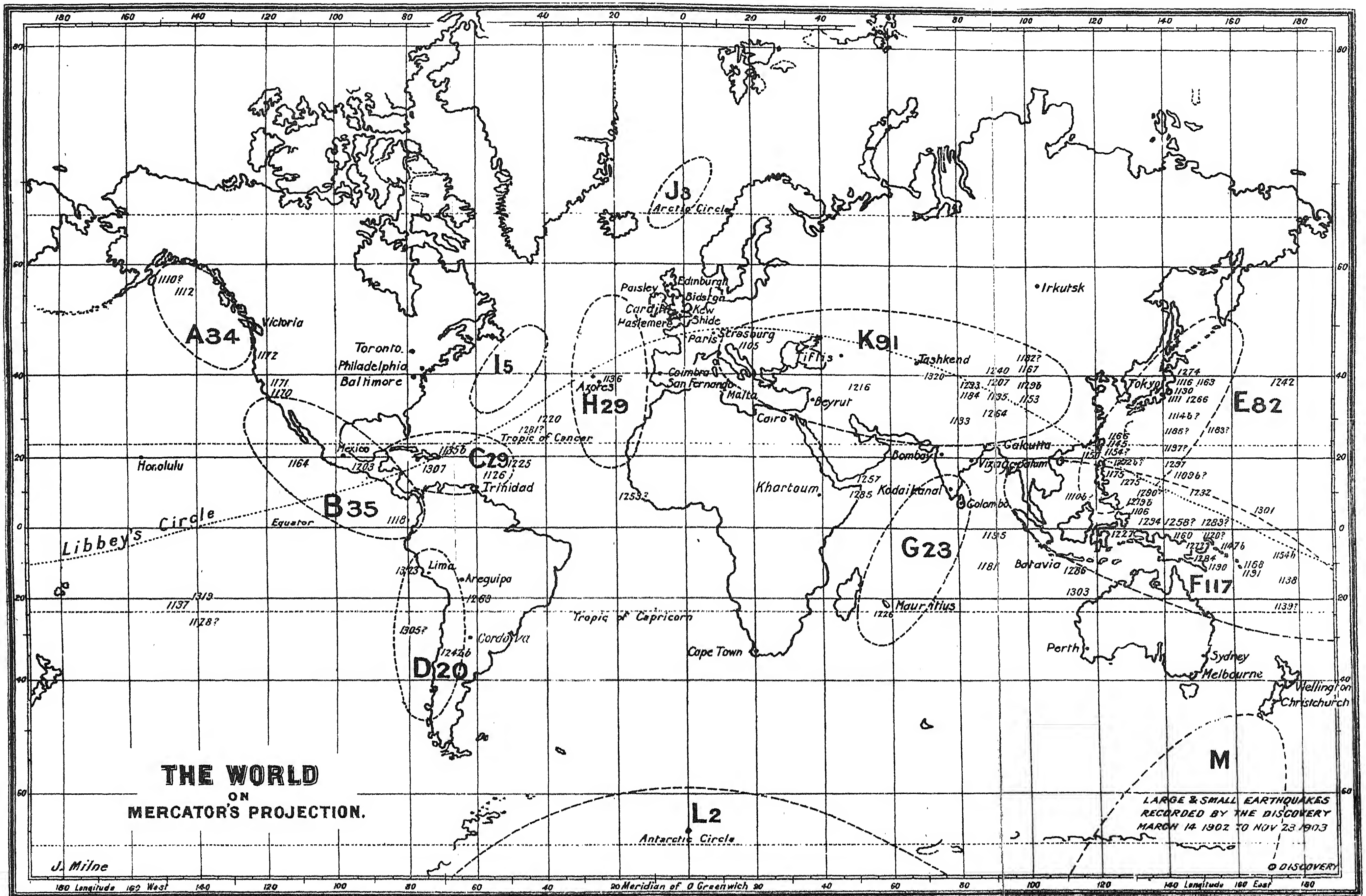
of a similar and similarly installed pendulum recording on a slowly moving surface. With very large earthquakes in which the preliminary tremors have comparatively large amplitudes, differences of this nature are not observable. Although attention is only called to the photographic recording apparatus used with seismographs, it is evident that the character of the results obtained from other instruments may also to some degree be dependent upon the speed of recording surfaces.

IV. *Origins and Relationships of Large Earthquakes in* 1906.

The number of entries in the Shide register for 1906 is 207. Out of this number ninety-two may be regarded as megaseismic in character. This number is distinctly above the average. On the accompanying map the origins of seventy-one of these are shown, the districts of greatest activity being *E* and *F*. The display of activity, however, to which public attention has been chiefly directed, occurred on the western shores of North and South America. On January 31 we had the Colombian earthquake, the origin of which was apparently sub-oceanic off the mouth of the Esmeralda River. This convulsion, which led to the interruption of several submarine cables, was followed by shocks in the Antilles. On April 4 a disastrous shaking took place in the Kangra Valley, in North-West India. Ten days later the Formosan earthquake occurred, which ruined 5,556 houses. On April 18 San Francisco was destroyed. Notwithstanding the intensity of the initial impulse, which, we are told, sent earth-waves twice round our world, it is astonishing how very little damage was done merely by the shaking of the ground. The greatest destruction was occasioned by fire. The origin of this disturbance was along lines of faults, which can be traced for distances of several hundreds of miles. The strike of these faults is apparently fairly parallel to the coast line, or from N.N.W. to S.S.E. The seismograms obtained at distant stations lying to the east or west of California, or at right angles to the fault, were very pronounced, whilst at Cordova, in South America, records were extremely small. Exactly the opposite occurred in the Jamaica earthquake which took place on June 14. In this case the strike of the fault or faults was east to west, and the seismograms in Europe, *i.e.*, to the east of Jamaica, were extremely small. On August 17 Valparaiso and the towns in its neighbourhood were reduced to ruin. In Greenwich mean time the Valparaiso earthquake occurred at 0h. 41m. 2s. Thirty-three minutes before this, or at 0h. 8m., or 0h. 11m. G.M.T., a very large earthquake took place beneath the North Pacific to the north of the Sandwich Islands. The time taken for the second phase of this shock to travel from its origin to Valparaiso, a distance of 122°, would be about 31 minutes. This time-interval suggests at least three possibilities: (*a*) The earth-waves from the North Pacific may have released a state of seismic strain in Chili; or (*b*) the earthquake in this latter country may represent an effort to establish a dynamical counterbalance consequent on a molar displacement in the North Pacific; or (*c*) the two disturbances were due to some common influence.

The fact that large earthquakes so frequently occur in pairs or groups precludes the idea that these short intervals between megaseismic effects are merely matters of chance.

Origins for 1906 are indicated by their B.A. Shide Register number. Earthquake districts are indicated A, B, C, &c., and the number of Earthquakes since 1899 which originated from these is expressed in large numerals. The two arcs from England to the Pacific Coast of America refer to the Note by Mr. R. D. Oldham in this Report.



Illustrating the Report on Seismological Investigations.

The epicentre for the first shock has been given at 40° N.L. and 170° or 180° E.L. (Milne), 30° N. and 170° E. (Oldham), and 50° N. and 170° E. (Ōmori).

V. *On the Apparently Luminous Effects from certain Rocks.*

The object of the following note is to show that at certain times surfaces of chalk or clay slate as they exist in mines and quarries give rise to continuous or sudden radiations which make an impression similar to that produced by light upon a photographic film. Various motives led to the experiments. Accounts of luminosity in the heavens or on hills at the time of large earthquakes are common. One of the last occasions upon which phenomena of this nature were observed was at the time of the Valparaiso earthquake, August 17, 1906. Mr. W. G. Davis, Director of the Meteorological Survey of Argentina, tells me that as seen by Captain Taylor from the deck of the R.M.S. 'Orissa,' lying fifty metres from the wharf at Valparaiso, there appeared upon the hills at a height of about 500 metres waves of light. These waves, which are compared with chain lightning, extended as far as the eye could reach, and lasted during the first shock, of nearly two minutes.

On these occasions strong earth-currents have affected the working of land lines, and needles of galvanometers have been disturbed. In Tokio the writer found that an electrometer, whether arranged to record the difference of potential between the earth and the atmosphere or between the surface of the ground and water-bearing strata at a depth of 30 feet, would from time to time suffer large displacements. The times at which certain of these were recorded agreed with the times of local earthquakes, and might therefore be regarded as the result of a mechanical disturbance. When these observations were made teleseismic unfelt movements had not yet been recorded, and it was therefore impossible to determine whether such disturbances had any true relationship with many unexplained electrometer perturbations. Now we know that unfelt earth-movements may be accompanied by movements of magnetic needles and disturbances in the records from electrometers. These and kindred observations suggested the possibility that a megaseismic collapse might not only produce mechanical disturbances through and over the world, but that part of the initial energy at the centrum might be converted into another form of energy which might be transmitted to all parts of the world simultaneously. When a territory equal in area to the British Islands is shattered to such a depth that the homogeneous nucleus of our earth is caused to vibrate, as we have indicated, a local transformation of energy in the form of light has occasionally been observed. But we have no definite information as to the distance this or its equivalent may be transmitted. The observation that from time to time a quarry in the Isle of Wight, known as Pan Chalk Pit, which I occasionally passed at night, appeared to be luminous also, suggested the possibility of hypogenic activities, giving evidence of their existence in the form of light. The pit or quarry faces north. In winter it is not reached by the sun. Its glowings, which apparently rise and fall in intensity, are most noticeable after a dull damp day.

To determine whether these appearances were real, and whether they might be connected with other phenomena, I made, with the permission of Mr. J. L. Warsap, the following experiments. At the end of a

chamber twenty yards from the mouth of a tunnel driven into the chalk, a hole about two feet square was excavated. Into this a box with a light-proof door was cemented. In this box a Richard self-recording thermometer drum covered with a Kodak bromide paper was placed. The drum, which was entirely made of brass, revolved at the rate of 40 millimetres per day. Between it and the chalk face, distant about half an inch, there was a sheet of zinc in which were two round holes respectively about an eighth and a quarter inch in diameter. One was below the other, and lower still there was a vertical slit. As the drum turned, the paper was exposed to the chalk through these openings. Experiments were continued for four months, ending May 8, 1903. During that interval photographic impressions were only obtained on three or four occasions. These were in the form of black discs, possibly representing the holes and straight lines for the slit. The first series read as follows: February 6, 6.30 P.M., 8.54 P.M.; February 7, 0.30 A.M. and 2.54 A.M. Nothing in the nature of a glow extending over several hours or anything coinciding in time with a large earthquake was recorded. It was, however, interesting to note that photographic effects had been obtained in a place and under conditions where it is difficult to imagine that they had been the result of artificially produced light.

For various reasons these experiments were not again taken up until August 19, 1906. On that date a piece of apparatus in many respects similar to that used in 1903 was put up in a dark chamber, cut in the chalk inside the tunnel leading to the Pan Chalk Pit. The chief differences between the new and the old installations were as follows: In the new apparatus the cylinder carrying the paper moved at the rate of 90 mm. per day. This shortened the exposure of the film as it passed before the holes in the zinc plate between it and the chalk face. The distance between the film and this plate was reduced to one-eighth inch, whilst an aluminium rim forming the bottom of the brass drum revolved inside a horizontal slit cut in the plate. The rim was at a distance not greater than one sixteenth inch from the top and bottom of the slit.

The drum stood inside a wooden case outside which at the distance of an inch was a second case. The dimensions and form of the holes in the zinc sheet which formed the end of the inner box were as follows: A round hole one-eighth inch in diameter, a triangular hole with half-inch sides vertically below the round one, and below this a square hole with sides of one inch. The holes were about an inch apart, and underneath the square hole was the slit, cut to free the rim of the drum.

The movement of a small electric lamp round the face and sides of the box produced no effect on the paper inside, and hence it may be inferred that the box was light-proof. A self-recording thermometer and a hygrometer between November 5 and 19 showed that the temperature and the moisture in the chamber were practically constant.

A similar piece of apparatus was, through the kindness of Mr. B. Angwin and Mr. J. G. Lawn, placed in the King Edward Mine, Camborne, Cornwall, at a depth of 160 feet. The rock was damp, as in Pan Chalk Pit. At both places cakes of calcium chloride were used to dry the atmosphere, but I cannot say they were effective. For about three months papers were exposed simultaneously with those at Shide, and the results were compared. Another piece of apparatus was set facing the chalk in a light-proof hut in White Pit Lane, between Shide and Carisbrooke. The drum was inclosed in a box (also light-proof) inside the hut. Its rate of

running was only a little over a half that of the instruments at Pan Chalk Pit and Camborne.

In each case the drums turned once a week, in which interval they used one sheet of bromide paper.

Amongst various control experiments which were made I may mention the following :—

I. Two pieces of chalk, one of which had been soaked for several hours in water, were placed over a piece of rapid bromide paper. Between the paper and the chalk there was an air space of about one millimetre. At the end of forty hours development showed that no effect of any description had been produced. Each piece of chalk had a surface of about four square inches.

II. For two weeks the instrument from the Pan Chalk Pit was mounted in my observatory, where a plastered brick wall took the place of the natural chalk face. To approximate to the conditions in the pit, inside the covering case a bowl of water and a wet sponge were placed. The developed films did not show any trace of photographic action. The ideas of making these last experiments arose from communications with the manager of the Kodak works at Harrow, who pointed out that effects had been produced upon photographic surfaces inclosed in dark slides made from aluminium, and also in apparatus where movable parts of aluminium and zinc were used. The drums used at Shide and at Camborne were made of brass and aluminium, and they passed very closely to a fixed sheet of zinc. But I have only got photographic effects when the apparatus was underground in the places described.

III. Several pieces of bromide paper have been inclosed in black envelopes and placed against the face of the chalk in the instrument chamber at the Pan Pit. After a week's contact there was no trace of photographic action on the film when it had been developed.

IV. Several pieces of bromide paper have been placed in envelopes which had a thin glass window which touched the chalk. After a week's exposure the paper opposite the window was sometimes blackened.

More Important Observations.

Pan Chalk Pit.

November 12 *to* 19, 1906.—12th, 14h. to 14th, 17h. 45m., strong singeings. At this time it was foggy and frosty. Intermittent singeings 30m. to 3h. apart.

November 19 *to* 26.—19th, 10h., to 21st, 10h., strong singeings. Weather frosty, finishing with rain. Up to 25th slight intermittent singeings. During this period there were many spots; one group agrees with a slight earthquake on 21st at 23h. 57m.

November 26 *to December* 3.—26th to 28th, spots fairly numerous. Singeings strong November 26th, 16h., to 27th, 6h. Weather dull and fine. Spots also numerous December, 3h. to 20h., and singeings (strong). Slight rain and stormy.

Camborne.

November 13 *to* 19, 1906.—No record, as paper had been exposed to light; still on it three parallel lines can be traced, made up apparently of a series of spots bounded by a luminous band.

November 19 *to* 24.—Parallel bands reproduced, but the dotted lines are broken. On 19th, 10h. to 20h., and 23rd, 10h., singeings; 19th, strongly marked.

November 24 *to December* 1.—Upper and lower luminous bands surrounding broken dotted line.

December 1 *to* 8.—Luminous bands and broken lines continue. Strong singeings December 1, 16h., to 3rd, 10h.; 4th, 10h.; 8th, 10h. Weather foggy and stormy.

December 10 *to* 17.—10th, 13h., 12th, 10h., heavy singeings; 13th, 17h., to 15th, 9h. 30m., heavy singeings. Luminous band opposite top small hole 13th A.M. to 16th noon.

December 24 *to* 31.—24th noon to 19h., intermittent singeings; 25th, 0h., to 29th, 15h., same; 29th, 21h., to 30th, 15h., same. A few spots.

December 31 *to January* 7, 1907.—31st, 12h., to January 1st, 6h., occasional singeings which continue at intervals of several hours up to January 3. January 4th, 3h., to 5th, 11h., intermittent singeings, only one or two spots.

January 22 *to* 29.—22nd to 28th, heavy singeings, most of time weather cold and frosty. Running along the top of singeings is a very fine line.

January 29 *to February* 5.—February 1st, 2h., slight singeings to 11h.

March 19 *to* 25.—19th, 10h., 16h. slight singeings.

March 25 *to April* 1.—Mere trace of singeings, 30th, 16h.

April 1 *to* 8.—1st, 11 A.M., slight singeings repeated at long intervals during week.

April 8 *to* 15.—Neither singeings, spots, nor bands. For most part weather showery and dull.

April 15 *to* 22.—Very slight singeings.

April 22 *to* 29.—Clear sheet.

December 8 *to* 15.—8th, 14h., luminous band, dotted lines; 9th to 10th, strong singeings, and 13th to 14th; 11th, very large spot 10h. 30m., 15 mm. diameter.

December 18 *to* 21.—Luminous bands. No records until March 18.

March 18 *to* 24, 1907.—Bands very faint.

March 23 *to* 28.—Two faint bands.

April 2 *to* 6.—2nd to 5th, luminous band with a chain-like pattern. Slight singeings 3rd, 12h., at intervals to 5th, 12h. From 3rd, 12h., to 4th, 12h., groups of large spots.

April 6 *to* 11.—From 6th to 10th intermittent singeings.

April 11 *to* 17.—12th to 17th, bands very faint.

April 17 *to* 23.—Two dark bands. 18th to 19th, slight singeings.

The Results.

The sheets of paper were changed once a week and were always found to be very damp. When they were developed, certain sheets were perfectly clear whilst others were partly or entirely marked with dark bands, black lines, round black spots, or semicircular spots along the lower edges. These latter, from their appearance of having been burnt, have been called singeings.

I. *Dark Bands.*—Those have not been very numerous, but were found four times out of twenty-nine sheets from Shide, eleven times out of twelve sheets from Camborne. They were never found on fourteen sheets from White Pit Lane. On removing the instrument at the latter place it was found that the zinc plate had so far buckled that the bromide paper may have been a quarter of an inch from the chalk. Those from Pan Chalk Pit were about one inch in width, being darker in the centre than near their edges. They occurred opposite the triangular hole, the edges of which touched the chalk. Those from Camborne varied much in character. In certain cases we appear to have had at least three bands, apparently coinciding with the three holes in the zinc plate interposed between the film and the rock surface. In some of these bands there were hard black lines broken along their length and made up of black spots.

II. *Black Spots.*—These vary in diameter from 1 mm. to 8 mm. In the centres of some of these there is a small white or brownish spot. As pointed out by Mr. W. H. Bullock of Newport, these closely resemble the spots produced when a piece of bromide paper is placed between the poles of an induction coil. Sometimes they were very numerous, and at other times only one, perhaps, was found on a sheet.

III. *Singeings.*—These occur on the lower edge of the paper where the brass cylinder joins the aluminium ring. They are sometimes continuous, or they may occur at intervals of half-an-hour to several hours on the length of a whole sheet. At other times only a group of two or three can be found during the entire week.

If we attach the secondary terminals of an induction coil, one to the zinc sheet and the other to the drum, bands, spots, and singeings closely simulating those recorded in the chalk pit may be obtained.

Between August 19, 1906, and January 29, 1907, sixty-three large and small earthquakes were recorded at Shide. Out of these only ten nearly coincided with the time of occurrence of spots upon the paper. As at times the spots were so very numerous, we can only regard these coincidences as accidental. So far as we can see, bands, singeings, and spots occur in any state of the weather, and are therefore not connected with any ordinary meteorological conditions.

Neither is there any distinct evidence that the markings are due to radio-activity. There appears, however, to be a suggestion that the luminosity occasionally seen at Pan Pit may result from a very feeble brush or glow-like electrical discharge. If this be so, it would also account for the bands on the photographic paper, the other markings being due to minute sparks.

If we assume that there are radio-active or electrical emanations of hypogenic origin from our earth, it is difficult to escape from the conclusion that such must have an effect on what we call 'climate,' and hence upon everything which lives upon the surface of the globe.

VI. *Earthquakes and Changes in Latitude.* *By* Professor C. G. Knott.

In the last report Professor Milne continued his interesting comparison of the occurrence of large earthquakes and the movements of the earth's pole. The table he gave seems to call for a further discussion. Milne's idea is to connect the occurrence of the earthquakes with the curvature of the path traced by the projection of the pole on the celestial sphere. But if there is to be any connection of the kind looked for, ought we not rather to consider the deviations from the mean value of the curvature or deflection (to use Milne's terminology) than the deflections themselves? For this mean curvature per tenth year we may consider to be due to some steadily acting dynamical cause, such as a slight departure from coincidence of the axis of rotation with the principal axis of inertia. From this point of view we should regard small deflections of 5° or 10° as being abnormal equally with large deflections of 60° or 70°. Hence the earthquake frequency should be compared with the deviations of the deflections from the mean, which for the whole set of observations is almost exactly 30·5. I shall take the two groups as given in the last report together. By subtracting the mean deflection from the average deflection in each range we obtain what I shall call deviations from mean curvature. These form the first and fourth columns in the following

table, the second and fifth containing the number of times this particular average deviation occurred; while the third and sixth columns contain the average number of earthquakes corresponding with the deviations.

Deviations from Mean	Number of Occurrences	Average Number of Earthquakes	Deviations from Mean	Number of Occurrences	Average Number of Earthquakes
−28	1	18	+ 2	17	12
−23	8	20·1	+ 7	16	12·5
−18	10	6·5	+ 12	10	11
−13	7	7·4	+ 17	8	17
− 8	15	9·7	+ 22	6	20
− 3	23	13·9	+ 37	2	21
			+ 37·3	5	24

The number of occurrences are given by way of contrast. It is obvious that they follow roughly the well-known law of grouping about a mean, the maximum being in the neighbourhood of zero deviation or mean deflection. But it is quite otherwise with the earthquake numbers. If there were no connection, direct or indirect, between the two phenomena, the earthquake numbers would be fairly constant throughout. There seems to be, however, a tendency toward greater values for higher deviations. For deviations up to $+12$ and -13 the averages total 66·5, or an average of 11·1. For deviations greater than these limits the averages total 126·6, or an average of 18·1. This conclusion lends a certain amount of support to Milne's view that there is some connection between the occurrence of large world-shaking earthquakes and the movements of the earth's pole.

The mean curvature of the path of the pole is 30·5 per tenth year, or 305 per annum. Hence the pole will make a complete revolution in $365 \times 360/305$ days, or 432 days. The value given by Chandler is 427 days. It is well known that a rigid body of the size, figure, and mass of the earth will have a small precessional motion of period—305 days if the axis of the figure is not quite coincident with the axis of diurnal revolution. To explain the large discrepancy between the observed value 427 and the theoretical value 305, Newcomb invoked the influence of elasticity in modifying the period of precessional rotation. His original calculation was admittedly approximate, and Hough[1] has worked out the problem in a more rigorous manner. Taking account of the elasticity only, he finds that the precessional period will have the value 427 days if the effective rigidity of the earth were a little greater than that of steel. Newcomb also pointed out that the mobility of the ocean would have the same effect of lengthening the precessional period. Further, if the effective rigidity of the earth were to diminish all over, the precessional period would be increased. It is not easy to see what would be the immediate effect of either a local diminution of rigidity or a local yielding to stresses such as takes place when an earthquake is originated. But it is at all events not unreasonable that some effect will be produced. This is probably the direction in which we must look for the connection imagined by Milne.

[1] 'Rotation of an Elastic Spheroid,' *Phil. Trans.*, vol. clxxxvii. A, 1896.

VII. *Note on the Duration of the First Preliminary Tremor in the San Francisco and Colombian Earthquakes. By* R. D. OLDHAM.

The great earthquakes of Colombia, January 31, 1906, and California, April 18, 1906, originated at not very greatly different distances from Western Europe, but reached it by very different wave-paths. The great circles from Shide, plotted on the map, show that in the former case the wave-paths lay under the broadest and deepest part of the Atlantic Ocean, and in the latter under the continent of North America and the continental shelf of the North Atlantic. In studying the records of these two earthquakes I found that there was a marked difference in the interval between the arrival of the first and the second phases of the preliminary tremors, the interval at Shide being 9·9 minutes for a distance of about 77·6 degrees in the Californian, and 11·9 m. for a distance of about 80·7 degrees in the Colombian, records. The difference between these two, viz., 2·0 minutes, is greater than the average, but a comparison of all the records from European observatories, at which these two phases can be recognised in the case of both earthquakes, gives mean intervals of 10·4 and 11·4 minutes for mean distances of 84° and 86° in the case of the Californian and Colombian earthquakes respectively. The difference in interval, corresponding with the difference in distance, is only 0·2 minute, or one-fifth of the observed difference. As these two phases of the record are due to wave-motion of different kinds, transmitted at different rates, through the earth, the difference in interval between their arrival indicates a difference in the ratio between their rates of transmission, and consequently a difference in the constitution of the matter under the North American continent and the North Atlantic Ocean. The exact time of occurrence of the Colombian earthquake being unknown from direct observation, it is not possible to compare the absolute rates of propagation and determine in what this difference consists, but it appears to be too great to be due to any error of record or interpretation, and may be accepted as real.

Magnetic Observations at Falmouth Observatory.—Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Dr. R. T. GLAZEBROOK (*Secretary*), Professor W. G. ADAMS, Dr. CHREE, Captain CREAK, Mr. W. L. FOX, Sir A. W. RÜCKER, *and* Professor SCHUSTER.

THE grant voted by the Association last year has been expended in maintaining the magnetic observations at Falmouth Observatory. The results of the observations have been published in the Annual Report of the National Physical Laboratory, as well as in that of the Royal Cornwall Polytechnic Society.

The mean value of the magnetic elements for the year 1906 are—

Declination . . .	18° 5′·3 W.
Horizontal Force . .	0·18790 C.G.S.
Vertical Force . .	0·43344 C.G.S.
Inclination . . .	66° 33′·7 N.

The Committee are informed that the observatory at Eskdale Muir will be ready for occupation this autumn. It is clearly important for the sake of continuity that the Falmouth Observatory should be fully maintained until Eskdale Muir is in complete working order. To secure this the Committee ask for reappointment, with a grant of 50*l*.

The Further Tabulation of Bessel Functions.—Report of the Committee, consisting of Professor M. J. M. HILL (*Chairman*), Dr. L. N. G. FILON (*Secretary*), *and* Professor ALFRED LODGE.

THE Committee were appointed for the purpose of continuing the investigation of the formulæ (see Report for 1906, pp. 494-498) relating to the semi-convergent series for the n^{th} Bessel function, viz.,

$$J_n(x)=\sqrt{\frac{2}{\pi x}}\cdot R\cos\left(x+\alpha-\frac{\pi}{4}-n\frac{\pi}{4}\right),$$

where $R^2=P^2+Q^2$

$$=1+\frac{1}{2}\cdot\frac{4n^2-1}{(2x)^2}+\frac{1\cdot 3}{2\cdot 4}\cdot\frac{(4n^2-1)(4n^2-3^2)}{(2x)^4}+\ldots$$

the values of P and Q being

$$P=1-\frac{(4n^2-1)(4n^2-3^2)}{1\cdot 2\cdot (8x)^2}+\frac{(4n^2-1)\ \ldots\ (4n^2-7^2)}{1\cdot 2\cdot 3\cdot 4(8x)^4}-\ldots$$

$$Q=\frac{4n^2-1}{8x}-\frac{(4n^2-1)(4n^2-3^2)(4n^2-5^2)}{1\cdot 2\cdot 3(8x)^3}+\ldots$$

and α being $\sin^{-1}\frac{Q}{R}$,

with a view to tabulating the logarithms of R and $R\sqrt{\frac{2}{\pi}}$ for different values of x and n, and also tabulating values of α. The values of $R\sqrt{\frac{2}{\pi}}\div\sqrt{x}$ give the amplitude of the function, and the values of α are needed to give its phase.

The formulæ relating to α are $R\sin\alpha=Q$, and $1+\frac{d\alpha}{dx}=\frac{1}{R^2}$, leading to a somewhat unsatisfactory series for α, viz. (writing $8k=4n^2-1$)

$$\alpha=\frac{k}{x}+\frac{k(k-3)}{6x^3}+\frac{k(k^2-14k+15)}{10x^5}+\frac{k(5k^3-190k^2+807k-630)}{56x^7}+$$

and lastly

$$\sec(\alpha_{n+1}-\alpha_n)=R_nR_{n+1},$$

which depends on the identity

$$P_nP_{n+1}+Q_nQ_{n+1}=1,$$

an identity which was obtained by induction, and needed to be verified by a deductive proof. This proof has now been obtained by Professor Hill, and is appended.

The Committee have calculated a series of values of log R and log $R\sqrt{\frac{2}{\pi}}$, which are here printed (see folding Tables I. and II.).

They have also calculated values of $\sin\alpha_0$ with a view to obtaining values of α_1, α_2, . . . by use of the equation $\sec(\alpha_{n+1}-\alpha_n)=R_nR_{n+1}$. The values of α_1, α_2, . . . they hope to give in a subsequent report. The

x	$n=0$
10	$\bar{1}$·9997 3277
20	$\bar{1}$·9999 3241
30	$\bar{1}$·9999 6989
40	$\bar{1}$·9999 8305
50	$\bar{1}$·9999 8915
60	$\bar{1}$·9999 9246
70	$\bar{1}$·9999 9446
80	$\bar{1}$·9999 9576
90	$\bar{1}$·9999 9665
100	$\bar{1}$·9999 9729
200	$\bar{1}$·9999 9932
300	$\bar{1}$·9999 9970
400	$\bar{1}$·9999 9983
500	$\bar{1}$·9999 9989
600	$\bar{1}$·9999 9992
700	$\bar{1}$·9999 9995
800	$\bar{1}$·9999 9996
900	$\bar{1}$·9999 9997
1000	$\bar{1}$·9999 9997

	n	
	$\bar{1}$·90:	728
	$\bar{1}$·90:	725
	$\bar{1}$·90	100
	$\bar{1}$·90	231
	$\bar{1}$·90:	292
	$\bar{1}$·90.	325
70	$\bar{1}$·90:	345
80	$\bar{1}$·90:	358
90	$\bar{1}$·90:	367
100	$\bar{1}$·901	373
200	$\bar{1}$·901	394
300	$\bar{1}$·901	398
400	$\bar{1}$·901	399
500	$\bar{1}$·901	400
600	$\bar{1}$·901	400
700	$\bar{1}$·901	400
800	$\bar{1}$·901	400
900	$\bar{1}$·901	400
	$\bar{1}$·901	

TABLE I.—*Values of log R to 8 decimals,*[1] *the last being approximate (required for the calculation of a).*

$n=\frac{1}{2}$	$n=1$	$n=1\frac{1}{2}$	$n=2$	$n=2\frac{1}{2}$	$n=3$	$n=3\frac{1}{2}$	$n=4$	$n=4\frac{1}{2}$	$n=5$	$n=5\frac{1}{2}$	$n=6$	$n=6\frac{1}{2}$
Nil	·0008 0548	·0021 6069	·0040 8534	·0066 0827	·0097 6881	·0136 1873	·0182 250..	·0236 7351	·0300 743..	·0375 6929	·0463 414..	·0566 2925
	·0002 0300	·0005 4219	·0010 1881	·0016 3465	·0023 9204	·0032 9393	·0043 4382	·0055 4591	·0069 0510	·0084 2711	·0101 1849	·0119 8678
	·0000 9036	·0002 4114	·0004 5258	·0007 2502	·0010 5893	·0014 5489	·0019 1356	·0024 3570	·0030 2224	·0036 7421	·0043 9277	·0051 7920
	·0000 5086	·0001 3568	·0002 5453	·0004 0753	·0005 9482	·0008 1659	·0010 7304	·0013 6441	·0016 9098	·0020 5307	·0024 5103	·0028 8526
	·0000 3256	·0000 8684	·0001 6288	·0002 6073	·0003 8044	·0005 2209	·0006 8576	·0008 7155	·0010 7957	·0013 0996	·0015 6284	·0018 3838
	·0000 2261	·0000 6031	·0001 1311	·0001 8103	·0002 6410	·0003 6236	·0004 7585	·0006 0461	·0007 4870	·0009 0818	·0010 8312	·0012 7359
	·0000 1662	·0000 4431	·0000 8310	·0001 3299	·0001 9400	·0002 6614	·0003 4944	·0004 4393	·0005 4963	·0006 6657	·0007 9479	·0009 3435
	·0000 1272	·0000 3393	·0000 6362	·0001 0181	·0001 4851	·0002 0372	·0002 6746	·0003 3974	·0004 2058	·0005 1001	·0006 0802	·0007 1469
	·0000 1005	·0000 2681	·0000 5027	·0000 8044	·0001 1733	·0001 6094	·0002 1128	·0002 6836	·0003 3220	·0004 0280	0004 8018	·0005 6433
	·0000 0814	0000 2171	·0000 4071	·0000 6515	·0000 9503	·0001 3035	·0001 7112	·0002 1733	·0002 6901	·0003 2616	·0003 8880	·0004 5690
	·0000 0204	·0000 0543	·0000 1019	·0000 1629	·0000 2376	·0000 3258	·0000 4276	·0000 5430	·0000 6720	·0000 8146	·0000 9708	·0001 1406
	·0000 0090		·0000 0452	·0000 0724	·0000 1056	·0000 1448	·0000 1900	·0000 2413	·0000 2986	·0000 3619	·0000 4314	·0000 5068
		·0000 0241										
	·0000 0051	·0000 0136	·0000 0254	·0000 0407	·0000 0593	·0000 0814	·0000 1068	·0000 1357	·0000 1679	·0000 2036	·0000 2426	·0000 2850
	·0000 0032	·0000 0087	·0000 0162	·0000 0260	·0000 0379	·0000 0521	·0000 0683	·0000 0868	·0000 1074	·0000 1303	·0000 1552	·0000 1824
	·0000 0022		·0000 0113	·0000 0181	·0000 0264	·0000 0362	·0000 0475	·0000 0603	·0000 0746	·0000 0905	·0000 1078	·0000 1267
		·0000 0060										
	·0000 0017	·0000 0044	·0000 0083	·0000 0133	·0000 0194	·0000 0266	·0000 0349	·0000 0443	·0000 0548	·0000 0665	·0000 0792	·0000 0931
	·0000 0013	·0000 0034	·0000 0064	·0000 0102	·0000 0148	·0000 0204	·0000 0267	·0000 0340	·0000 0420	·0000 0509	·0000 0606	·0000 0712
	·0000 0010	·0000 0027	·0000 0050	·0000 0080	·0000 0117	·0000 0161	·0000 0211	·0000 0268	·0000 0332	·0000 0402	·0000 0479	·0000 0563
	·0000 0008	·0000 0022	·0000 0041	·0000 0065	·0000 0095	·0000 0130	·0000 0171	·0000 0217	·0000 0269	·0000 0326	·0000 0388	·0000 0456

[1] Some of the logarithms are calculated to 7 decimals only, when $x=10$.

TABLE II.—*Values of log* $R\sqrt{\frac{2}{\pi}}$ *to 7 decimals, for finding the amplitude* $R\sqrt{\frac{2}{\pi x}}$.

$n=\frac{1}{2}$	$n=1$	$n=1\frac{1}{2}$	$n=2$	$n=2\frac{1}{2}$	$n=3$	$n=3\frac{1}{2}$	$n=4$	$n=4\frac{1}{2}$	$n=5$	$n=5\frac{1}{2}$	$n=6$	$n=6\frac{1}{2}$
1·9019 401 (throughout)	$\bar{1}$·9027 455	$\bar{1}$·9041 007	$\bar{1}$·9060 254	$\bar{1}$·9085 483	$\bar{1}$·9117 089	$\bar{1}$·9155 588	$\bar{1}$·9201 651	$\bar{1}$·9256 136	$\bar{1}$·9320 144	$\bar{1}$·9395 094	$\bar{1}$·9482 815	$\bar{1}$·9585 693
	$\bar{1}$·9021 431	$\bar{1}$·9024 823	$\bar{1}$·9029 589	$\bar{1}$·9035 747	$\bar{1}$·9043 321	$\bar{1}$·9052 340	$\bar{1}$·9062 839	$\bar{1}$·9074 860	$\bar{1}$·9088 452	$\bar{1}$·9103 672	$\bar{1}$·9120 586	$\bar{1}$·9139 268
	$\bar{1}$·9020 304	$\bar{1}$·9021 812	$\bar{1}$·9023 926	$\bar{1}$·9026 651	$\bar{1}$·9029 990	$\bar{1}$·9033 950	$\bar{1}$·9038 536	$\bar{1}$·9043 758	$\bar{1}$·9049 623	$\bar{1}$·9056 142	$\bar{1}$·9063 328	$\bar{1}$·9071 193
	$\bar{1}$·9019 909	$\bar{1}$·9020 757	$\bar{1}$·9021 946	$\bar{1}$·9023 476	$\bar{1}$·9025 349	$\bar{1}$·9027 567	$\bar{1}$·9030 131	$\bar{1}$·9033 045	$\bar{1}$·9036 310	$\bar{1}$·9039 931	$\bar{1}$·9043 911	$\bar{1}$·9048 253
	$\bar{1}$·9019 726	$\bar{1}$·9020 269	$\bar{1}$·9021 029	$\bar{1}$·9022 008	$\bar{1}$·9023 205	$\bar{1}$·9024 622	$\bar{1}$·9026 258	$\bar{1}$·9028 116	$\bar{1}$·9030 196	$\bar{1}$·9032 500	$\bar{1}$·9035 029	$\bar{1}$·9037 784
	$\bar{1}$·9019 627	$\bar{1}$·9020 004	$\bar{1}$·9020 532	$\bar{1}$·9021 211	$\bar{1}$·9022 042	$\bar{1}$·9023 024	$\bar{1}$·9024 159	$\bar{1}$·9025 447	$\bar{1}$·9026 888	$\bar{1}$·9028 482	$\bar{1}$·9030 232	$\bar{1}$·9032 137
	$\bar{1}$·9019 567	$\bar{1}$·9019 844	$\bar{1}$·9020 232	$\bar{1}$·9020 730	$\bar{1}$·9021 341	$\bar{1}$·9022 062	$\bar{1}$·9022 895	$\bar{1}$·9023 840	$\bar{1}$·9024 897	$\bar{1}$·9026 066	$\bar{1}$·9027 349	$\bar{1}$·9028 744
	$\bar{1}$·9019 528	$\bar{1}$·9019 740	$\bar{1}$·9020 037	$\bar{1}$·9020 419	$\bar{1}$·9020 886	$\bar{1}$·9021 438	$\bar{1}$·9022 075	$\bar{1}$·9022 798	$\bar{1}$·9023 606	$\bar{1}$·9024 501	$\bar{1}$·9025 481	$\bar{1}$·9026 547
	$\bar{1}$·9019 501	$\bar{1}$·9019 669	$\bar{1}$·9019 903	$\bar{1}$·9020 205	$\bar{1}$·9020 574	$\bar{1}$·9021 010	$\bar{1}$·9021 513	$\bar{1}$·9022 084	$\bar{1}$·9022 722	$\bar{1}$·9023 429	$\bar{1}$·9024 202	$\bar{1}$·9025 044
	$\bar{1}$·9019 482	$\bar{1}$·9019 618	$\bar{1}$·9019 808	$\bar{1}$·9020 052	$\bar{1}$·9020 351	$\bar{1}$·9020 704	$\bar{1}$·9021 112	$\bar{1}$·9021 574	$\bar{1}$·9022 091	$\bar{1}$·9022 662	$\bar{1}$·9023 289	$\bar{1}$·9023 970
	$\bar{1}$·9019 421	$\bar{1}$·9019 455	$\bar{1}$·9019 503	$\bar{1}$·9019 563	$\bar{1}$·9019 638	$\bar{1}$·9019 726	$\bar{1}$·9019 828	$\bar{1}$·9019 944	$\bar{1}$·9020 073	$\bar{1}$·9020 215	$\bar{1}$·9020 371	$\bar{1}$·9020 541
	$\bar{1}$·9019 410	$\bar{1}$·9019 425	$\bar{1}$·9019 446	$\bar{1}$·9019 473	$\bar{1}$·9019 506	$\bar{1}$·9019 545	$\bar{1}$·9019 591	$\bar{1}$·9019 642	$\bar{1}$·9019 699	$\bar{1}$·9019 763	$\bar{1}$·9019 832	$\bar{1}$·9019 907
	$\bar{1}$·9019 406	$\bar{1}$·9019 414	$\bar{1}$·9019 426	$\bar{1}$·9019 441	$\bar{1}$·9019 460	$\bar{1}$·9019 482	$\bar{1}$·9019 507	$\bar{1}$·9019 536	$\bar{1}$·9019 569	$\bar{1}$·9019 604	$\bar{1}$·9019 643	$\bar{1}$·9019 686
	$\bar{1}$·9019 404	$\bar{1}$·9019 409	$\bar{1}$·9019 417	$\bar{1}$·9019 427	$\bar{1}$·9019 439	$\bar{1}$·9019 453	$\bar{1}$·9019 469	$\bar{1}$·9019 487	$\bar{1}$·9019 508	$\bar{1}$·9019 531	$\bar{1}$·9019 556	$\bar{1}$·9019 583
	$\bar{1}$·9019 403	$\bar{1}$·9019 407	$\bar{1}$·9019 412	$\bar{1}$·9019 419	$\bar{1}$·9019 427	$\bar{1}$·9019 437	$\bar{1}$·9019 448	$\bar{1}$·9019 461	$\bar{1}$·9019 475	$\bar{1}$·9019 491	$\bar{1}$·9019 508	$\bar{1}$·9019 527
	$\bar{1}$·9019 402	$\bar{1}$·9019 405	$\bar{1}$·9019 409	$\bar{1}$·9019 414	$\bar{1}$·9019 420	$\bar{1}$·9019 427	$\bar{1}$·9019 436	$\bar{1}$·9019 445	$\bar{1}$·9019 455	$\bar{1}$·9019 467	$\bar{1}$·9019 480	$\bar{1}$·9019 494
	$\bar{1}$·9019 402	$\bar{1}$·9919 404	$\bar{1}$·9019 407	$\bar{1}$·9019 411	$\bar{1}$·9019 415	$\bar{1}$·9019 421	$\bar{1}$·9019 427	$\bar{1}$·9019 435	$\bar{1}$·9019 443	$\bar{1}$·9019 452	$\bar{1}$·9019 461	$\bar{1}$·9019 472
	$\bar{1}$·9019 402	$\bar{1}$·9019 403	$\bar{1}$·9019 406	$\bar{1}$·9019 409	$\bar{1}$·9019 412	$\bar{1}$·9019 417	$\bar{1}$·9019 422	$\bar{1}$·9019 427	$\bar{1}$·9019 434	$\bar{1}$·9019 441	$\bar{1}$·9019 449	$\bar{1}$·9019 457
	$\bar{1}$·9019 401	$\bar{1}$·9019 403	$\bar{1}$·9019 405	$\bar{1}$·9019 407	$\bar{1}$·9019 410	$\bar{1}$·9019 414	$\bar{1}$·9019 418	$\bar{1}$·9019 422	$\bar{1}$·9019 428	$\bar{1}$·9019 433	$\bar{1}$·9019 439	$\bar{1}$·9019 446

values of sin α_0 are given in Table III., and also those of log $(-x \sin \alpha_0)$, which latter series is useful for purposes of interpolation.

TABLE III.—*Values of* $Q_0(x)$ *and* log $\{-Q_0(x)\}$, *&c.*

x	$Q_0(x)$	log $(-Q_0(x))$	log $(-\sin \alpha_0)$	$-\sin \alpha_0$	log $(-x \sin \alpha_0)$
10	–·012 428 881	$\bar{2}$·0944,3203	$\bar{2}$·0946,9926	·012,436,531	$\bar{1}$·0946 9926
20	–·006 240 9144	$\bar{3}$·7952,4822	$\bar{3}$·7953,1581	·006,241,886	$\bar{1}$·0963 4581
30	–·004 163 9632	$\bar{3}$·6195,0688	$\bar{3}$·6195,3699	·004,164,252	$\bar{1}$·0966 5824
40	–·003 123 8578	$\bar{3}$·4946,9125	$\bar{3}$·4947,0820	·003,123,980	$\bar{1}$·0967 6819
50	–·002 499 4148	$\bar{3}$·3978,3835	$\bar{3}$·3978,4920	·002,499,477	$\bar{1}$·0968 1920
60	–·002 082 9945	$\bar{3}$·3186,8813	$\bar{3}$·3186,9567	·002,083,031	$\bar{1}$·0968 4692
70	–·001 785 5309	$\bar{3}$·2517,6737	$\bar{3}$·2517,7291	·001,785,554	$\bar{1}$·0968 7095
80	–·001 562 3571	$\bar{3}$·1937,8030	$\bar{3}$·1937,8454	·001,562,372	$\bar{1}$·0968 7453
90	–·001 388 7884	$\bar{3}$·1426,3609	$\bar{3}$·1426,3944	·001,388,799	$\bar{1}$·0968 8195
100	– 001 249 9268	$\bar{3}$·0968,8458	$\bar{3}$·0968,8729	·001,249,935	$\bar{1}$·0968 8729
200	–·000 624 9908	$\bar{4}$·7958,7363	$\bar{4}$·7958,7431	·000,624,992	$\bar{1}$·0969 0431
300	–·000 416 6640	$\bar{4}$·6197,8598	$\bar{4}$·6197,8628	·000,416,664	$\bar{1}$·0969 0753
400	–·000 312 4989	$\bar{4}$·4948,4849	$\bar{4}$·4948,4866	·000,312,499	$\bar{1}$·0969 0865
500	–·000 249 9994	$\bar{4}$·3979,3897	$\bar{4}$ 3979,3908	·000,250,000	$\bar{1}$.0969 0908
600	–·000 208 3330	$\bar{4}$·3187,5806	$\bar{4}$·3187,5814	·000,208,333	$\bar{1}$·0969 0939
700	–·000 178 5712	$\bar{4}$·2518,1141	$\bar{4}$·2518,1147	·000,178,571	$\bar{1}$·0969 0951
800	–·000 156 2499	$\bar{4}$·1938,1975	$\bar{4}$·1938,1979	·000,156,250	$\bar{1}$·0969 0978
900	–·000 138 8888	$\bar{4}$·1426,6723	$\bar{4}$·1426,6728	·000,138,889	$\bar{1}$·0969 0979
1000	–·000 124 9999	$\bar{4}$·0969,0967	$\bar{4}$·0969,0980	·000,125,000	$\bar{1}$·0969 0980

They have also obtained approximate expressions for α_n for a few special values of n when x is very large. The extent to which these approximations can be depended on will have to be verified when the tables of α have been formed. It seems better to postpone the report on these approximations until such verification can be made; but it may be stated that a good approximation to α_0 is $\alpha_0 = -\frac{1}{10}\cot^{-1}\frac{4x}{5}$.

The following are accurate:

$$\alpha_{\frac{1}{2}} = 0.$$

$$\alpha_{\frac{3}{2}} = \cot^{-1}x.$$

$$\alpha_{\frac{5}{2}} = \cot^{-1}\frac{2x+\sqrt{3}}{3} + \cot^{-1}\frac{2x-\sqrt{3}}{3}$$

The Committee desire reappointment, with a continuation of their present grant.

APPENDIX.

Report of the Committee appointed in 1906 *to consider the Further Calculation of Bessel's Functions.*

In the communication on this subject made to Section A in 1906, it was stated by Professor Lodge that the equation

$$P_n P_{n+} + Q_n Q_{n+} = 1,$$

where

$$P_n=1-\frac{(4n^2-1^2)(4n^2-3^2)}{2\,!\,(8x)^2}+\frac{(4n^2-1^2)(4n^2-3^2)(4n^2-5^2)(4n^2-7^2)}{4\,!\,(8x)^4}-\ldots$$

and

$$Q_n=\frac{4n^2-1^2}{(8x)}-\frac{(4n^2-1^2)(4n^2-3^2)(4n^2-5^2)}{3\,!\,(8x)^3}+\ldots,$$

was probably true.

The following is an outline of the proof, which is much shortened by adopting the abbreviation $(a, a+2s)$ for the product of the $(s+1)$ factors $a, a+2, a+4, \ldots (a+2s)$.

With this notation

$$P_n=1-\frac{(2n-3,\ 2n+3)}{2\,!\,(8x)^2}+\ldots+(-1)^r\frac{(2n-4r+1,\ 2n+4r-1)}{(2r)\,!\,(8x)^{2r}}+\ldots$$

$$Q_n=\frac{(2n-1,\ 2n+1)}{1\,!\,(8x)}-\frac{(2n-5,\ 2n+5)}{3\,!\,(8x)^3}-\ldots$$

$$+(-1)^{r-1}\frac{(2n-4r+3,\ 2n+4r-3)}{(2r-1)\,!\,(8x)^{2r-1}}+\ldots$$

On forming the expression $P_nP_{n+1}+Q_nQ_{n+1}$ the coefficient of $(-1)^r\frac{1}{(8x)^{2r}}$ will be found to consist of $(2r+1)$ terms, of which

the first is $1\,.\,\frac{(2n-4r+1,\ 2n+4r-1)}{(2r)\,!}$;

the second is $-\frac{(2n+1,\ 2n+3)}{1\,!}\ \frac{(2n-4r+3,\ 2n+4r-3)}{(2r-1)\,!}$;

the $(t+1)^{\text{th}}$ is

$$(-1)^t\frac{(2n-2t+3,\ 2n+2t+1)}{t\,!}\ \frac{(2n-4r+2t+1,\ 2n+4r-2t-1)}{(2r-t)\,!};$$

the $(2r)^{\text{th}}$ is $-\frac{(2n-4r+5,\ 2n+4r-1)}{(2r-1)\,!}\ \frac{(2n-1,\ 2n+1)}{1\,!}$,

and the $(2r+1)^{\text{th}}$ is $\frac{(2n-4r+3,\ 2n+4r+1)}{(2r)}$.

In order to prove that $P_nP_{n+1}+Q_nQ_{n+1}=1$ it is necessary to prove that the coefficient of $(-1)^r\frac{1}{(8x)^{2r}}$ is zero.

If the r^{th} term in the series, which expresses the value of this coefficient, be denoted by T_r, it will be found that

$$T_{r+1}+T_{r+2}=\frac{(-1)^r(2n-2r-1,\ 2n+2r+1)(2n-2r+3,\ 2n+2r-3)}{r(r-1)\,!\,(r+1)\,!}$$

$$T_{r+1}+(T_{r+2}+T_r)+T_{r+3}$$

$$=\frac{(-1)^{r+1}2(2n-2r-3,\ 2n+2r+3)(2n-2r+5,\ 2n+2r-5)}{r(r-2)\,!\,(r+2)\,!}.$$

Then the induction

$$T_{r+1}+(T_{r+2}+T_r)+\ .\ .\ .\ +(T_{r+s}+T_{r-s+2})+T_{r+s+1}=$$
$$\frac{(-1)^{r+s+1}s(2n-2r-2s+1,\ 2n+2r+2s-1)(2n-2r+2s+1,\ 2n+2r-2s-1)}{(r-s)\,!\,(r+s)\,!\,r}$$

can be verified by adding in the two terms $T_{r-s+1}+T_{r+s+2}$.

Putting $s=r-1$, the value of

$$T_{r+1}+(T_{r+2}+T_r)+\ .\ .\ .\ +(T_{2r-1}+T_3)+T_{2r}$$

is found; and adding in the remaining terms, T_2, T_{2r+1}, and T_1, the result is found to vanish.

Thus the equation $P_nP_{n+1}+Q_nQ_{n+1}=1$ is proved.

The expression found by Professor Lodge for $P_n^2+Q_n^2$ from the differential equation which it satisfies has also been verified by a direct calculation, but the work is so long that the Committee do not feel justified in asking the Association to print it.

The Teaching of Elementary Mechanics.—Report of the Committee, consisting of Professor HORACE LAMB (*Chairman*), Professor J. PERRY (*Secretary*), Mr. C. VERNON BOYS, Professors CHRYSTAL, EWING, G. A. GIBSON, *and* GREENHILL, Principal GRIFFITHS, Professor HENRICI, Dr. E. W. HOBSON, Mr. C. S. JACKSON, Sir OLIVER LODGE, Professors LOVE, MINCHIN, SCHUSTER, *and* A. M. WORTHINGTON, *and* Mr. A. W. SIDDONS, *appointed for the Consideration of the Teaching of Elementary Mechanics, and the Improvement which might be effected in such Teaching.*

THE Committee make the following suggestions. Some of these are copied from the Report of the Mathematical Association Committee on the Teaching of Elementary Mechanics:—

1. Practical and theoretical mechanics ought, if possible, to be taught by the same person; mechanics and mathematics ought not to be treated as distinct from each other.

2. The opportunity furnished by the necessity for writing an account of what a student has done and seen in his laboratory work ought to be utilised in relation to the teaching of English composition.

3. The theoretical study of mechanics should be preceded and accompanied by concrete experience of some of the facts to be dealt with in the systematic course; for example, such things as are used in practical engineering and such as can be met with in ordinary life.

4. An experimental course might include mensuration, geometry, weighing, and measuring; the equilibrium of forces, the lever and other simple machines, force of friction, and the effect of friction in simple machines; work, forms of energy, especially the energy of lifted weights, kinetic energy, heat; hydrostatics, barometers, pumps; velocity, acceleration, inertia, force.

5. Examples should at first, as a rule, be numerical, and should, as far as possible, be of a practical nature. A specially instructive class of

example consists in compiling a table or drawing a graph to show the effect on a result of variation in a certain datum.

6. Graphical and analytical methods of study, involving the use of mathematical instruments, squared paper, and tables of logarithms, sines, &c., ought to go hand in hand throughout the teaching of mechanics.

7. Pupils should always be required to specify the body whose equilibrium or motion is being considered, and to indicate the complete system of forces acting on the body, before writing down any equations.

8. Simplifying assumptions, such as that friction, stiffness of ropes, weights of certain bodies, &c., are being disregarded in any particular question, cannot be too explicitly stated.

9. Some statics should precede kinetics.

10. The parallelogram or triangle of forces should be assumed as an experimental result.

11. The impression that the weight of a body is in reality a single force acting at its centre of gravity should be guarded against.

12. The consideration of work should be an essential part of the discussion of machines, and attention should at an early stage be given to 'velocity-ratio' and 'efficiency.'

13. When the equilibrium of two or more connected bodies or parts of a single body is considered, it is helpful to attend to the separate equilibrium of each part.

14. It should be clearly pointed out that all the results of statics apply to cases of uniform motion.

15. *Velocity.*—The meaning of the phrase 'velocity at an instant' should be carefully brought out by means of the idea of 'average velocity.' Average velocity should be defined as 'total distance/total time,' and should not be assumed to be identical with the arithmetic mean of the initial and final velocities, or with the velocity at half-time, or with the velocity at half-way. There should be no objection to illustrating the idea of a *rate* so as to lead up to the elementary ideas and methods of the calculus.

16. *Angular velocity* should receive attention, as in connection with it a great variety of interesting kinematic examples arise.

17. *Acceleration.*—The velocity at any time should be represented graphically. This method should be used to illustrate the idea of acceleration, and the formulæ for uniformly accelerated motion may be obtained from the fact that the graph is in this case a straight line.

18. The formulæ for uniform acceleration having been proved, the fact that 'the average velocity = the velocity at the middle instant' should be frequently employed in solving problems connected with such motion.

19. It is convenient to treat elementary problems on the accelerations produced by forces by simple proportion,

$$\frac{\text{force acting}}{\text{weight}} = \frac{\text{acceleration produced}}{g},$$

using the fact that a body's own weight produces acceleration g; and it is convenient to postpone the consideration of mass or inertia until such problems have been discussed.

20. Students ought to know the meaning of 'absolute measure'; that is, they should be able to interpret all fundamental equations such

as $E=\frac{1}{2}mv^2$, or $F=mdv/dt$, in any consistent system of units whatever. They should learn that for certain purposes the C.G.S. system of units is convenient, and for certain other purposes the units employed by British engineers may be convenient; they should not be dominated by any system, but able to use them all. The *poundal* and other such educational conveniences should be used as auxiliary units only, final results being expressed in units to which practical people are accustomed, so as to be generally intelligible.

21. Atwood's machine should be regarded as a means of illustrating the laws of motion, and not as an accurate method of finding g.

22. With the idea of preventing the notion that acceleration is always uniform, and having regard to the importance in physics of simple harmonic motion, it is advisable to consider such motion and the pendulum at an early stage.

23. Easy problems on the motion of a fly-wheel should form part of a course on elementary mechanics.

24. Centrifugal force should never be dealt with as if applied to the moving body, so as to reduce an essentially kinetic problem to a spuriously statical one. It is a force exerted by a curvilinearly moving body on its constraints.

Investigation of the Upper Atmosphere by means of Kites in co-operation with a Committee of the Royal Meteorological Society.—Sixth Report of the Committee, consisting of Dr. W. N. Shaw (*Chairman*), Mr. W. H. Dines (*Secretary*), Mr. D. Archibald, Mr. C. Vernon Boys, Dr. R. T. Glazebrook, Dr. H. R. Mill, Professor A. Schuster, *and* Dr. W. Watson. (*Drawn up by the Secretary.*)

Meetings of the Joint Committee were held on November 13, 1906; also on January 24, May 9, May 23, and July 5, 1907.

Observations have been made at Glossop Moor by Mr. J. E. Petavel, F.R.S., whose report on the subject is appended.

The Committee have had under consideration a circular sent out by Professor Hesgesell, the President of the International Aëronautical Commission. In it he asks for the co-operation of England in a special series of kite and balloon ascents, and the Committee have arranged for some ascents, in addition to those undertaken by the Meteorological Office, on the specified days.

At the meeting of the Joint Committee held on May 9 it was suggested that the British Association Committee should ask for reappointment and for a grant of 25*l.*

Glossop Moor Kite Station (Peak District). Report for the Session 1906–1907. *By* J. E. Petavel, *F.R.S.*

This kite station was established in the spring of 1906 by Mr. G. C. Simpson.

The necessary winding gear was purchased by aid of a grant from the Royal Meteorological Society; the other initial and current expenses have been defrayed by the Manchester University.

During the present session some sixty successful ascents have been made, Messrs. T. V. Pring and W. A. Harwood having kindly acted as voluntary assistants.

Miss Margaret White has undertaken an analytical study of the records obtained, and proposes to give a short account of the results of the work at the coming meeting of the British Association.

Recently the Government Grant Committee of the Royal Society have awarded the funds required to complete and perfect the apparatus installed at this station.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLaren (*Chairman*), Professor Crum Brown (*Secretary*), Sir John Murray, Professor F. W. Dyson, *and* Mr. R. T. Omond.

As mentioned in the report for 1905, the meteorological observations on Ben Nevis have now ceased, but the Committee have co-operated with the Scottish Meteorological Society in the discussion of the observations made on Ben Nevis and at Fort William during the twenty-one years that the observations were carried on. This discussion was conducted under the direction of the late Dr. Alexander Buchan, but owing to his death on May 13 last no report can be furnished this year. It is proposed that the discussion be continued by Mr. Omond and others during the ensuing year.

The observations made at the high and low level observatories from the opening of the Ben Nevis Observatory in 1883 till the end of 1897 have been published, and those for two additional years—1898 and 1899—are in type. The observations to the end of 1887 were published by the Royal Society of Edinburgh. The cost of printing those of the succeeding twelve years—1888 to 1899 inclusive—has been defrayed by a grant of 500*l*. from the Royal Society of London and another grant of 500*l*. from the Royal Society of Edinburgh. There still remain nearly five years' observations in manuscript—namely, from January 1900 to September 1904. The Committee consider it exceedingly desirable that these last observations should also be published, so that the whole record from the Ben Nevis Observatory be made available to meteorologists.

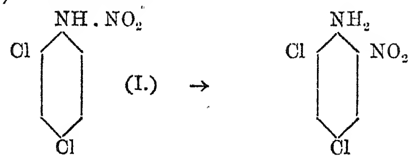
The estimated cost of printing these observations is 400*l*., and towards this the Royal Society of Edinburgh has offered a grant of 200*l*., spread over four years, on condition that the remainder of the money be obtained from other sources The Royal Society of London has voted 50*l*. for this object, so that there is still a sum of 150*l*. required to make up the 400*l*. necessary for the complete publication of the Ben Nevis records.

The Committee hope that the British Association will see its way to make up this deficiency by a grant from its funds, so as to enable the printing to go forward. The Committee beg to point out that it is some years since a grant was asked for the Ben Nevis work, and that at present there are no funds available for the purpose except what have been promised by the two scientific societies.

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.—Report of the Committee, consisting of Professor F. S. KIPPING (*Chairman*), Professor K. J. P. ORTON (*Secretary*), Dr. S. RUHEMANN, Dr. A. LAPWORTH, *and* Dr. J. T. HEWITT.

I. *Nitroamines.* (*With* W. W. REED, *B.Sc.*)

A DETAILED study of the conditions governing the transformation of 2 : 4-dichloro-1-nitroaminobenzene (I.)[1] into the isomeric 2 : 4-dichloro-6-nitroaniline (II.) has been made :



(I.) → (II.)

This nitroamine was chosen for particular study in preference to others, having different positions vacant (ortho and para relative to the group, $NH.NO_2$) into which the nitro-group may 'wander,' on account of the ease of its preparation,[2] and the non-basic character of the nitroaniline, of the above constitution, which is produced in the isomeric change. In testing the effect of minute quantities of acids as transforming agents, it is of great importance that the aniline should not be able to unite with the reagent, which would thus be withdrawn from the sphere of action.

A particular advantage which this transformation offers, in contrast to many others of a similar type, is due to the fact that the nitroamine is quite colourless, and forms colourless solutions, which may be preserved for long periods, whereas the nitroaniline crystallises in intensely yellow needles, and forms highly coloured solutions. Traces of the nitroaniline could thus be recognised, not only in solutions, but also in the crystals of the nitroamine. The conversion of the crystalline nitroamine into the nitroaniline is not merely indicated by a simple change of colour, but by the growth of yellow needles of the nitroaniline, apparently out of the colourless nitroamine—a process which can be readily followed photographically. This phenomenon, which can be demonstrated with a single crystal of the nitroamine, has allowed of the testing of the effect of single (necessary gaseous) reagents as transforming agents in the absence of all solvent.

The nitroamine was dried by sealing it up with phosphorus pentoxide in glass tubes. When thus entirely freed from water the substance acquires greater stability, and loses a remarkable sensitiveness to light, which necessitates the use of a dark room when aqueous solutions are employed.

After seven days' drying in this manner the tubes were opened, the reagent introduced, and the tube resealed. The reagent, which was in most cases in aqueous solution (0·1–0·2 c.c.), was enclosed in a small tube, and was separated from the dried nitroamine by a column of phosphorus pentoxide, five to six inches in length. The water slowly evaporated, and was absorbed by the pentoxide, the gaseous reagent, now

[1] Orton, *Trans. Chem. Soc.*, 1902, **81**, 802.
[2] Orton, *Berichte d. Chem. Gesell.*, 1907, **40**, 370.

anhydrous, diffusing to the region containing the nitroamine, of which at most one or two crystals (plates or needles) were used. Obviously this procedure admits only of the use of reagents which are not changed by prolonged contact with phosphorus pentoxide.

By this means it has been ascertained that hydrogen chloride, bromide and iodide, nitric acid, chlorine, or bromine can all act as transforming agents. Iodine, hydrogen cyanide (?), sulphur dioxide, carbon dioxide, and methyl iodide are inactive.

Quantitative experiments carried out with hydrogen chloride have revealed the very interesting fact that there is a limiting concentration (partial pressure) below which hydrogen chloride does not initiate the molecular rearrangement. In the case of the nitroamine here dealt with the partial pressure of the hydrogen chloride must be approximately 1/30 atmosphere.

The behaviour of the nitroamine with hydrogen chloride in various solvents was investigated, the most instructive results being obtained in aqueous solution. The solution of the nitroamine in pure water can apparently be preserved indefinitely in a dark room, no trace of colour becoming perceptible, notwithstanding the fact that it is easy to perceive the colour communicated by 1/10 mgr. of the nitroaniline to 100 c.c. of the solution; that is, to detect the transformation of 0·1 per cent. of the nitroamine. The addition of hydrogen chloride causes transformation, provided that the acid is above a certain concentration. The nitroamine was used at a concentration of V=207 (1 gr. per litre), the concentration of the acid being varied from N to N/1000. In all the solutions but that last mentioned, in which the molecular ratio $C_6H_3Cl_2 . NH . NO_2HCl$ was 5/1, the acid was in excess. The presence of the nitroaniline can be detected with certainty at the end of ten minutes in the N solution, and after longer periods down to a concentration of N/200, below which concentration all change ceases. Similar results were obtained with other acids, but, keeping the concentration of the nitroamine constant, the limiting value of the effective concentrations of the acids varies with the strength of the acid.

In the hope of isolating some compound of the acid and the nitroamine, hydrogen chloride, accurately dried, was passed into a solution of the nitroamine in petroleum. A colourless compound separated, which was resolved by solutions of alkalis into the nitroamine and hydrogen chloride, but when kept in a dry atmosphere the compound slowly changed into the nitroaniline.

These remarkable results greatly illuminate the mysterious part played in this type of intramolecular change by the transforming agent (or catalyst), the necessity for the presence of which was first recognised by Armstrong.[1]

The deductions to be drawn from these observations may be thus summarised:—

(i) No 'specific' reagent is required for any given transformation.

(ii) The reagent must be capable of combining with the nitroamine. In all probability this union is effected directly with the nitrogen of the NH group, which thus becomes quinquevalent. The additive product in the case of hydrogen chloride has a composition represented by the formula $C_6H_3Cl_2 . NH . NO_2,HCl$.

[1] *Report*, 1899, p. 683, and cf. *Trans. Chem. Soc.*, 1900, 77, 1053.

(iii) No transformation occurs in aqueous solution when the concentration of the transforming agent is below a certain value (for hydrochloric acid below N/200), the nitroamine being at a dilution of $V = 207$. The additive compound is apparently completely 'hydrolysed' at such dilution.

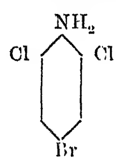
(iv) The additive compound is not formed from gaseous hydrogen chloride and the nitroamine when the pressure of the former is below a certain value—namely, the dissociation pressure of the compound. This pressure is approximately 1/30 atmosphere at 15° C.

It has been suggested [1] that the additive compound of the nitroamine and the transforming agent is alone capable of undergoing those further changes, probably through the transitory conversion of the benzene nucleus into a quinonoid form, by which the nitro-group 'wanders' from the nitrogen into the nucleus, whereas the simple nitroamine has no such power.

II. *The Wandering of Bromine in the Chlorination of Bromoanilines.* (*With* W. W. Reed, *B.Sc.*)

Although the replacement of bromine by chlorine in anilines [2] and in bromobenzenediazonium chlorides [3] has been observed, the displacement of bromine by chlorine from a given position in the benzene nucleus, followed, however, by a subsequent re-entry in another position, has not been described.

In the chlorination of *p*-bromoaniline, either by the usual method of passing chlorine into a solution in benzene or chloroform, or by the more delicate procedure of adding the requisite quantity of a solution of chlorine, or, finally, by using solutions of the aniline and chlorine (in the correct proportions, $C_6H_4Br . NH_2/2Cl_2$) in 20 per cent. hydrochloric acid, the expected 2 : 6-dichloro-4-bromoaniline



is not alone obtained. It is always mixed with 2 : 4-dibromo-6-chloro- and *s*-trichloro-anilines, and cannot be separated from them. The aniline can, however, be prepared in a pure state by indirect chlorination of the *p*-bromoaniline in chloroform solution with a solution of 2 : 4-dichloroacetylchloraminebenzene in the same solvent, thus:

$$C_6H_4Br . NH_2 + 2C_6H_3Cl_2 . NCl . AC = C_6H_2Cl_2Br . NH_2 + 2C_6H_3Cl_2 . NH . AC$$

Under these conditions displacement of bromine does not occur.

Similar results were obtained by chlorinating 2 : 4-dibromoaniline in hydrochloric acid solution. On subjecting *o*-bromo, *m*-bromo, or 2 : 6-dibromo-aniline to a similar treatment no such displacement was observed, each substance yielding a single chloro-derivative.

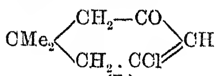
[1] Orton, *Proc. Roy. Soc.*, 1901, **71**, 153.

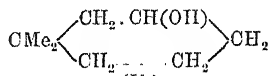
[2] Wegscheiden, *Monatsheft*, **18**, 329; Chattaway and Orton, *Trans. Chem. Soc.*, **79**, 822.

[3] Hantzsch, *Berichte d. Chem. Gesell.*, **30**, 2334.

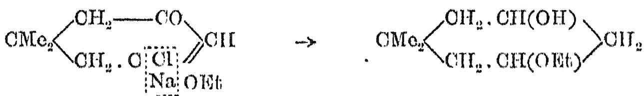
The Study of Hydro-aromatic Substances.—Report of the Committee, consisting of Dr. E. DIVERS (*Chairman*), Professor A. W. CROSSLEY (*Secretary*), Professor W. H. PERKIN, Dr. M. O. FORSTER, *and* Dr. H. R. LE SUEUR.

1. *The Action of Reducing Agents on* 5-*chloro*-3-*keto*-1 : 1-*dimethyl*-Δ^4-*tetrahydrobenzene*.[1]—Some little time since[2] it was shown that the principal product obtained by the action of sodium in moist ethereal solution on chloroketodimethyltetrahydrobenzene (I.) was 3-hydroxy-1 : 1-dimethylhexahydrobenzene (II.), which may be described as the


(I.)


(II.)

limit-reduction product of the chloroketone. A further study of the reaction has proved that the addition of a small quantity of alcohol to the ether has a beneficial effect, considerably increasing the yield of hydroxydimethylhexahydrobenzene, and rendering it much easier to remove the chlorine completely from the chloroketone. As alcohol had such a decided influence it was thought advisable to try the reduction with sodium in absolute alcoholic solution. The reaction proceeded, however, in an unexpected direction, and demonstrated the fact that the chlorine atom in chloroketodimethyltetrahydrobenzene is very reactive, a fact which greatly enhances the possibilities of the use of this and similar chloroketones for synthetical purposes. Small quantities of hydroxydimethylhexahydrobenzene (II.), but principally 3-*hydroxy*-5-*ethoxy*-1 : 1-*dimethylhexahydrobenzene* (IV.), were obtained, and it is evident that the sodium

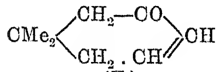

(III.) (IV.)

ethoxide formed in the first stages of the reduction reacts with the chlorine atom of the chloroketone to give the substance represented by formula III., which is then further reduced to the corresponding saturated compound. The constitution of the latter is proved by analysis and by the facts that a Zeisel determination shows it to contain an ethoxy-group, and that, when treated with acetyl- or benzoyl-chlorides, it yields acetyl- or benzoyl-derivatives respectively.

The main object of the investigation was, however, to find reducing agents, less powerful than sodium in moist ethereal solution, which would be discriminating in their action ; so that it might be possible to prepare from chloroketodimethyltetrahydrobenzene, first, a ketodimethyltetrahydrobenzene, differing from the former only in that chlorine would be replaced by hydrogen, and, secondly, the corresponding ketodimethylhexahydrobenzene. Complete success has attended the experiments, and further work is in progress with the object of proving that the reactions are general ones.

[1] Crossley and Renouf, *J.C.S.*, 1907, 91, 63.
[2] *Ibid.*, 1905, 87, 1487.

The next reducing agent employed was zinc-dust in aqueous alcoholic solution, which, as previously shown,[1] readily replaces halogen by hydrogen in saturated hydro-aromatic substances, but in the present instance its action is too powerful, as it gives a mixture of the ketones represented by formulæ V. and VI., containing approximately 30 per cent. of the latter. However, 3-*keto*-1 : 1-*dimethyl*-Δ^4-*tetrahydrobenzene* (V.) may be



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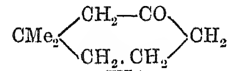
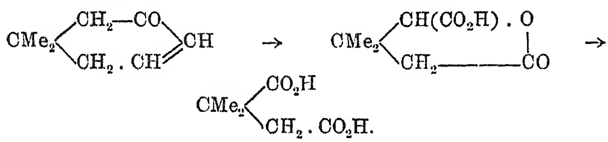
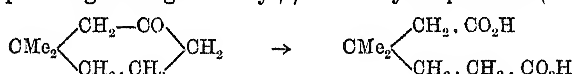


(VI.)

obtained quite pure by replacing zinc-dust by zinc-filings, either in the cold or on heating, or by using the zinc copper couple. It is a colourless liquid, boiling at 88·5° at 32 mm., and its ketonic nature is proved by the fact that it gives a semicarbazone and an oxime. When oxidised with potassium permanganate in the cold it yields *as*-dimethylsuccinic acid and the lactone of α-hydroxy-ββ-dimethylglutaric acid :



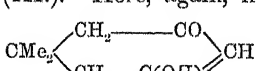
3-*Keto*-1 : 1-*dimethylhexahydrobenzene* (VI.) may be produced from chloroketodimethyltetrahydrobenzene by heating it with zinc-dust in glacial or dilute acetic acid solution. It is a colourless liquid, boiling about 10° lower (75·5° at 25 mm.) than the corresponding unsaturated ketone. It forms an oxime and a semicarbazone, and when oxidised with potassium permanganate gives only ββ-dimethyladipic acid (VII.), a fact



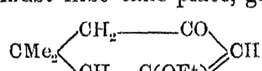
(VII.)

which proves its constitution beyond doubt.

Other reducing agents investigated were zinc-dust in strongly alkaline solution, also zinc-dust and hydrogen chloride in alcoholic solution. In the former case the hydrolytic action of the potassium hydroxide overshadows the reducing action of the zinc, with the result that the only product isolated was dimethyldihydroresorcin (VIII.). In the latter case a mixture of ketodimethyltetrahydrobenzene and ketodimethylhexahydrobenzene was obtained, together with dimethyldihydroresorcin and its ethyl ether [2] (IX.). Here, again, hydrolysis must first take place, giving rise



(VIII.)



(IX.)

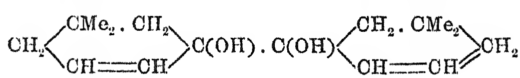
to dimethyldihydroresorcin, which is then esterified by the alcoholic hydrogen chloride.

Dicyclic Compounds.—The compounds of this nature met with are all derivatives of a substance formed theoretically by the removal of one hydrogen atom from each of two hexahydrobenzene rings, with

[1] *J.C.S.*, 1905, **87**, 1497 ; 1906, **89**, 43.
[2] *Ibid.*, 1899, **75**, 775.

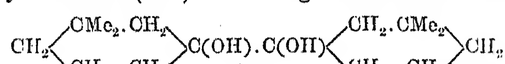
consequent production of dicyclic derivatives. It has been decided to refer to this substance as di*cyclo*hexane, and to indicate the positions of the various substituting groups by adopting the following scheme of numbering :

When zinc-dust acts on chloroketodimethyltetrahydrobenzene in aqueous solution, there is obtained a mixture of ketodimethyltetrahydrobenzene and ketodimethylhexahydrobenzene (V. and VI.), in which the former largely predominates. If this mixture of ketones is again treated several times with zinc-dust it is possible to isolate pure ketodimethylhexahydrobenzene and a semi-solid mass from which a crystalline product has been separated, melting at 148°. It has the composition $C_{16}H_{26}O_2$, is believed to be 1 : 1′-*dihydroxy*-5 : 5 : 5′ : 5′-*tetramethyl*-$\Delta^{2:2'}$-*di*cyclo*hexene* (X.), and owes its orgin to pinacone formation. Moreover its



(X.)

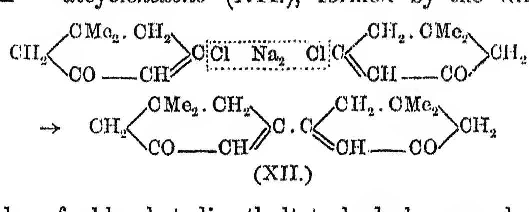
behaviour is quite in accord with that of a substance having formula X., for it does not give a colour reaction with concentrated sulphuric acid, nor can it be acetylated or benzoylated under the conditions employed. Further, its unsaturated nature is proved by the facts that it readily absorbs bromine, and when treated with sodium in moist ethereal solution it absorbs four atoms of hydrogen to give 1 : 1′-*dihydroxy*-5 : 5 : 5′ : 5′-*tetramethyldi*cyclo*hexane* (XI.). Here again this saturated pinacone does



(XI.)

not give a colour reaction with concentrated sulphuric acid, but it is surprising to find that it is acetylated or benzoylated very readily, though no explanation of this fact can be offered on the present occasion.

In the preparation of hydroxydimethylhexahydrobenzene considerable difficulty was experienced at one time in obtaining the product free from halogen, and on examining the resinous by-product formed under these conditions two solid substances were separated from it, melting respectively at 178° and 173°–174°. The former of these has the composition $C_{16}H_{22}O_2$ and is apparently 3 : 3′-*diketo*-5 : 5 : 5′ : 5′-*tetramethyl*-$\Delta^{1:1'}$-*di*cyclo*hexene* (XII.), formed by the direct coupling



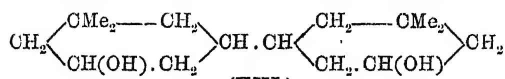
(XII.)

of 2 molecules of chloroketodimethyltetrahydrobenzene by the sodium. It is highly coloured (yellow), gives a brick-red disemicarbazone, thus proving its diketonic nature, and is unsaturated as shown by its ready

absorption of bromine. It could not be detected in the resin formed when alcohol was added to the ether used in the reduction of chloroketodimethyltetrahydrobenzene, but much larger quantities of the second substance melting at 173°–174° and also another compound melting sharply at 212° were isolated. The latter proved to be identical with 1 : 1′-dihydroxy-5 : 5 : 5′ : 5′-tetramethyldi*cyclo*hexane (XI.).

For a long time the substance melting at 173°–174° was thought to be homogeneous, as it gave on analysis numbers agreeing with the formula $C_{16}H_{30}O_2$, nor was its melting-point altered by many recrystallisations, and, moreover, it sublimed in needles which melted at 171°–172°. Nevertheless it was found to be a mixture, for on acetylation it gave two diacetyl derivatives melting at 130° and 68°, and on benzoylation two dibenzoyl derivatives melting at 199° and 134°. The former of the diacetyl and dibenzoyl compounds (m.-p. 130° and 199°) proved to be diacetyl- and dibenzoyl-1 : 1′-dihydroxy-5 : 5 : 5′ : 5′-tetramethyldi*cyclo*hexane, which substance they yielded on hydrolysis.

The above-mentioned derivatives melting at 68° and 134° were separately hydrolysed with alcoholic potassium hydroxide, when they each gave a substance, $C_{16}H_{30}O_2$, melting at 183°, which is believed to be 3 : 3′-*dihydroxy*-5 : 5 : 5′ : 5′-*tetramethyldi*cyclo*hexane* (XIII.). It is

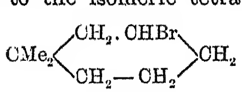


(XIII.)

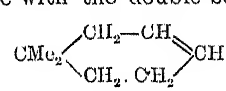
readily acetylated and benzoylated, and, unlike the unsaturated or saturated pinacones, gives a decided colour reaction with sulphuric acid. Its formation would be due to the further reduction of diketotetramethyldi*cyclo*hexene (XII.), although, unfortunately, sufficient of the latter material could not be isolated to try the action of reducing agents upon it.

The substance melting at 173°–174° is therefore a mixture of 1 : 1′-dihydroxy-5 : 5 : 5′ : 5′-tetramethyldi*cyclo*hexane (XI.) and 3 : 3′-dihydroxy-5 : 5 : 5′ : 5′-tetramethyldi*cyclo*hexane (XIII.), and it would appear, therefore, that in the reduction of chloroketodimethyltetrahydrobenzene with sodium in moist ethereal solution dicyclic compounds are formed both by the process of pinacone formation and by the coupling reaction of the sodium.

2. *Action of Alcoholic Potassium Hydroxide on 3-Bromo-1 : 1-Dimethylhexahydrobenzene.*[1]—The preparation of 3-bromo-1 : 1-dimethylhexahydrobenzene (XIV.) has been previously described,[2] and also the action of alcoholic potassium hydroxide on this substance,[3] which was stated to give rise to 1 : 1-dimethyl-Δ^3-tetrahydrobenzene (XV.) only, and not to the isomeric tetrahydrobenzene with the double bond in the



(XIV.)

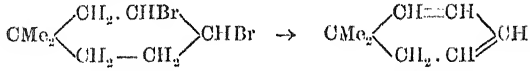


(XV.)

Δ^2-position. This conclusion, which was based on the result of oxidation experiments, was so unexpected that it appeared desirable further to investigate the supposed 1 : 1-dimethyl-Δ^3-tetrahydrobenzene, especially as there appeared to be a fairly easy means of deciding the point at issue.

[1] Crossley and Renouf, *J.C.S.*, 1906, **89**, 1556.
[2] *Ibid.*, 1905, **87**, 1497.
[3] *Ibid.*, p. 1499.

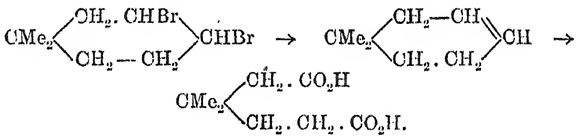
If this hydrocarbon has the constitution represented by formula XV., then on treatment with bromine it would give rise to 3 : 4-dibromo-1 : 1-dimethylhexahydrobenzene (XVI.), which, on treatment with a reagent



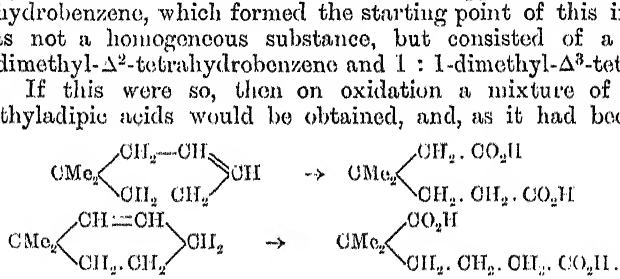
(XVI.) (XVII.)

capable of removing the elements of hydrogen bromide, should yield 1 : 1-dimethyl-$^{2:4}$-dihydrobenzene (XVII.).[1] But though the hydrocarbon obtained by the action of quinoline on the dibromodimethylhexahydrobenzene had the odour and gave the colour reaction characteristic of 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene, it has been proved by analysis and a study of its oxidation products to be an undoubted mixture of dimethyldihydro- and dimethyltetrahydro-benzenes.

Being under the misapprehension that the dibromodimethylhexahydrobenzene, from which the mixture of hydrocarbons had been prepared, was a homogeneous substance, the oxidation products expected were *as*-dimethylsuccinic acid, resulting from the oxidation of the dimethyldihydrobenzene, and $\beta\beta$-dimethyladipic acid, from the oxidation of the dimethyltetrahydrobenzene.



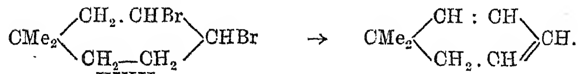
Instead there were actually obtained $\alpha\alpha$-dimethyladipic and *as*-dimethylsuccinic acids. This at once proved that the tetrahydrobenzene contained in the mixture of hydrocarbons must have been 1 : 1-dimethyl-Δ^2-tetrahydrobenzene, and therefore that the supposed 1 : 1-dimethyl-Δ^3-tetrahydrobenzene, which formed the starting point of this investigation, was not a homogeneous substance, but consisted of a mixture of 1 : 1-dimethyl-Δ^2-tetrahydrobenzene and 1 : 1-dimethyl-Δ^3-tetrahydrobenzene. If this were so, then on oxidation a mixture of $\alpha\alpha$- and $\beta\beta$-dimethyladipic acids would be obtained, and, as it had been found



possible, contrary to the statement of Blanc,[2] to separate these two acids,[3] a further quantity of 20 grams of dimethyltetrahydrobenzene[4] was prepared and oxidised with potassium permanganate.[5] There was no difficulty in proving that the solid product obtained consisted of a mixture of $\alpha\alpha$- and $\beta\beta$-dimethyladipic acids, in which the latter largely predominated, thus proving definitely the correctness of the above inference regarding the composition of the substance previously described as 1 : 1-dimethyl-Δ^3-tetrahydrobenzene.

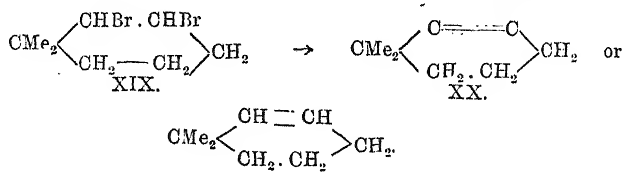
[1] *J.C.S.*, 1902, **81**, 832.
[2] *Bull. Soc. chim.*, 1905 [iii], **33**, 889.
[3] Crossley and Renouf, *J.C.S.*, 1906, **89**, 1552.
[4] *Ibid.*, 1905, **87**, 1499.
[5] *Ibid.*, p. 1502.

It follows from the above evidence that the supposed 3 : 4-dibromo-1 : 1-dimethyl-hexahydrobenzene[1] is a mixture of this substance with the corresponding 2 : 3-dibromo-derivative. When treated with quinoline the former (XVIII.) loses the elements of hydrogen bromide to give 1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene, which forms the main portion of the resulting mixture of hydrocarbons. But in the case of 2 : 3-dibromo-



XVIII.

1 : 1-dimethyl-hexahydrobenzene (XIX.) the removal of the hydrogen bromide cannot take place in an exactly similar manner, because the carbon



XIX. XX.

atom to which the *gem*-dimethyl group is attached has no hydrogen atoms in connection with it. The reaction might take place, giving rise to a substance of formula XX. containing a treble bond, or the two bromine atoms might be alone removed, possibly as a quinoline bromide. The former suggestion does not seem probable, because, although the hydrocarbon would give *aa*-dimethyladipic acid on oxidation, it would be isomeric with dimethyldihydrobenzene, but analysis showed the substance to be a mixture of dimethyldihydro- and dimethyltetrahydro-benzenes. In the latter case 1 : 1-dimethyl-Δ^2-tetrahydrobenzene would result, which would also give *aa*-dimethyladipic acid on oxidation, and, furthermore, its presence would be in agreement with the analytical data.

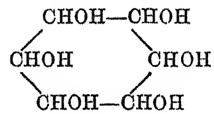
Recent Work on Hydro-aromatic Substances.
By Professor A. W. Crossley.

Hydrocarbons.—The ozonides of hydro-aromatic hydrocarbons[2] produced by the direct addition of ozone to a double bond in a six carbon ring, differ markedly from analogous derivatives obtained from open chain hydrocarbons, or from members of the aromatic series, in being very stable towards water. Thus the ozonide of 1 : 1 : 3-trimethyl-Δ^3-tetrahydrobenzene (cyclogeraniolene) is with difficulty acted on by water; the ozonide of tetrahydrobenzene is slowly changed by boiling with water, yielding principally adipic acid and small quantities of adipic aldehyde, whereas the ozonide of dihydroxylene does not give any definite products. Furthermore, the ozonides of hydro-aromatic hydrocarbons show irregularities in their composition, for though tetrahydrobenzene ozonide has the normal composition $C_6H_{10}O_3$, the derivative obtained from 1 : 1 : 3-trimethyl-Δ^3-tetrahydrobenzene appears to contain four atoms of oxygen and to possess a double molecular weight. This alone would not preclude the use of such substances for the determination of the constitution of

[1] Crossley and Renouf, *J. C. S.*, 1905, **87**, 1501.
[2] Harries and Neresheimer, *Ber.*, 1906, **39**, 2846.

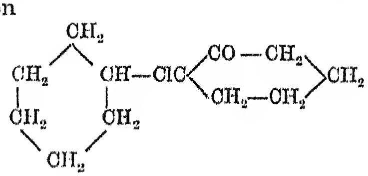
hydro-aromatic hydrocarbons if they were not so difficult to decompose with water. It has, however, now been ascertained that reduction of the ozonides leads to the production of the same aldehydes or ketones as would be formed by the action of water; or, if very energetic reducing agents are employed, to the corresponding alcohols. But the method possesses the disadvantage that it is not so easy to make a quantitative estimation of the products as when the decomposition is brought about by water.

Alcohols.—Scyllite, discovered in 1856, by Staedeler in certain cartilaginous fishes, has been further examined by Müller.[1] It has the formula $C_6H_{12}O_6$, forms monoclinic crystals melting in the neighbourhood of 360°, is but slightly soluble in water, is optically inactive, and gives a hexacetyl derivative. It is concluded from this evidence that scyllite is a hexahydroxyhexahydrobenzene, and is one of the inactive forms of inosite.

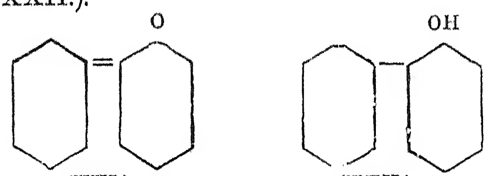


Ketones.—Ketohexahydrobenzene, like phloroglucinol and dihydroresorcin, is capable of existing in two tautomeric forms, either as the ketone or as hydroxy-Δ^1-tetrahydrobenzene, for when heated with acetic anhydride and sodium acetate[2] it yields the acetyl derivative of hydroxytetrahydrobenzene. The latter is a colourless oil boiling at 180°–182° and possessing a pleasant fruity odour. It is readily oxidised by potassium permanganate, giving adipic acid, and is hydrolysed by alcoholic potassium hydroxide with regeneration of ketohexahydrobenzene.

Condensation products of a varied nature have been obtained from ketohexahydrobenzene; thus when hydrogen chloride is passed into the pure ketone[3] a solid product results, having the formula $C_{12}H_{19}OCl$, and the probable constitution



This substance loses hydrogen chloride to form cyclohexene-cyclohexanone (XXI.), which on reduction gives the corresponding saturated alcohol (XXII.).

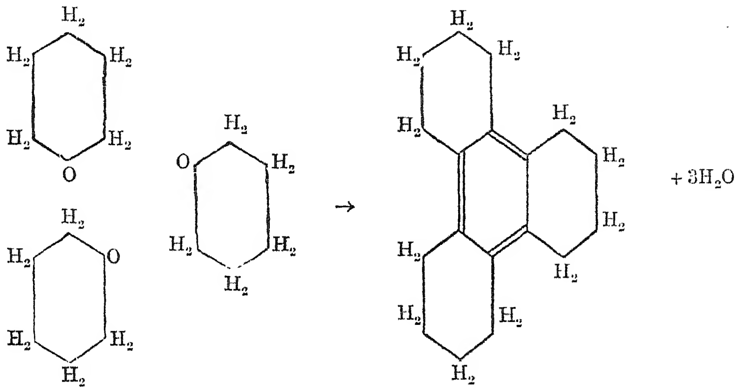


(XXI.) (XXII.)

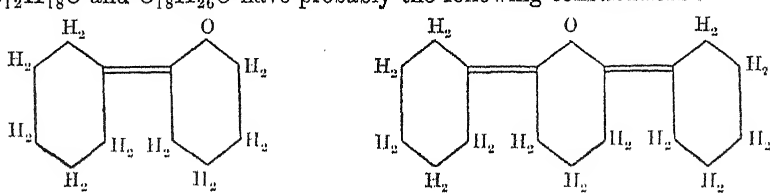
From this latter body, by treatment with hydrogen iodide, the fully hydrogenised dicyclohexane or dicyclohexyl $C_6H_{11} . C_6H_{11}$ is formed.

[1] *Ber.*, 1907, 40, 1821. [2] Mannich, *Ber.*, 1906, 39, 1594.
[3] Wallach, *Ber.*, 1907, 40, 70.

If alcoholic sulphuric acid be used as condensing agent, then Mannich[1] finds that ketohexahydrobenzene behaves similarly to acetone, yielding bodies analogous, as regards method of formation, to mesityl oxide, phorone, and mesitylene, and having the respective formulæ $C_{12}H_{18}O$, $C_{18}H_{26}O$, and $C_{18}H_{24}$. The latter would obviously be produced from three molecules of ketohexahydrobenzene, according to the following scheme:



which shows it to contain a benzene ring and three hydrogenised benzene rings, and it would therefore be dodecahydrotriphenylene. It crystallises in compact prisms melting at 232°–233°, when oxidised with fuming nitric acid yields mellitic acid, and on distillation with zinc-dust in an atmosphere of hydrogen[2] is converted into triphenylene, identical with the substance previously described by Schmidt and Schultz.[3] The ketones $C_{12}H_{18}O$ and $C_{18}H_{26}O$ have probably the following constitutions:



Homologues of ketohexahydrobenzene can be produced by the slow distillation of the anhydrides of substituted pimelic acids, when they lose carbon dioxide. Blanc[4] has by this means prepared from $\beta\beta$-dimethylpimelic anhydride 3-keto-1 : 1-dimethylhexahydrobenzene,[5] which when reduced with sodium and absolute alcohol gives 3-hydroxy-1 : 1-dimethylhexahydrobenzene, identical in every respect with the product obtained by Crossley and Renouf[6] by the reduction of chloroketodimethyltetrahydrobenzene. 3-Keto-1 : 1 : 4-trimethylhexahydrobenzene has been prepared by a similar reaction.

1 : 2-, 1 : 3-, and 1 : 4-ketomethylhexahydrobenzenes.[7]

2-Chloro-1-ketohexahydrobenzene is obtained by treating ketohexa-

[1] *Ber.*, 1907, **40**, 153.
[2] *Ibid.*, p. 159.
[3] *Annalen*, 1880, **203**, 135.
[4] *Compt. rend.*, 1907, **144**, 143.
[5] Compare p. 105 of this report.
[6] Compare p. 104 of this report.
[7] Wallach, *Annalen*, 1906, **346**, 249.

hydrobenzene suspended in water with chlorine in presence of calcium carbonate.[1] When boiled with a strong solution of potassium carbonate it is converted into 2-hydroxy-1-ketohexahydrobenzene, and when treated by Grignard's reaction yields ketomethyl-(ethyl, &c.)-hexahydrobenzene.

A compound isomeric with Pinner's xylitone is formed by the action of sodium ethoxide on a mixture of ethyl acetoacetate and phorone,[2] and is supposed to be 1-keto-3-isobutenyl-5 : 5-dimethyl-Δ^2-tetrahydrobenzene,

$$CH_2\left\langle\begin{array}{l}CO\text{ --- }CH\\ C(CH_3)_2\text{—}CH_2\end{array}\right\rangle C\text{—}CH=C(CH_3)_2.$$

It yields a tetrabromide, and when reduced with sodium and alcohol gives 1-hydroxy-3-isobutyl-5 : 5-dimethylhexahydrobenzene, which under the influence of phosphorus pentoxide loses water to form 3-isobutenyl-5 : 5-dimethyl-Δ^1-tetrahydrobenzene.

Acids.—Marckwald and Meth[3] have further investigated 1-methylcyclohexylideneacetic acid, to which allusion was made in the last report.[4]

$$CH_3.CH\left\langle\begin{array}{l}CH_2\text{—}CH_2\\ CH_2\text{—}CH_2\end{array}\right\rangle C=CH.COOH.$$

This acid shows the general property of an $\alpha\beta$-unsaturated acid, in that, when heated, it readily loses the elements of carbon dioxide to give a hydrocarbon, C_8H_{14}, which is optically inactive and has already been proved by Wallach to be 1-methyl-4-ethylenehexahydrobenzene.

$$CH_3.CH\left\langle\begin{array}{l}CH_2\text{—}CH_2\\ CH_2\text{—}CH_2\end{array}\right\rangle C=CH_2.$$

Further, as is well known, the bromo-additive compounds of $\alpha\beta$-unsaturated acids readily lose carbon dioxide and hydrogen bromide to give brominated hydrocarbons :—

$$R.CHBr.CHBr.COOH \rightarrow R.CH:CHBr.$$

Methylcyclohexylideneacetic acid behaves in a similar way,[5] for when treated with bromine in aqueous sodium carbonate solution it is converted into 1-methyl-4-bromomethylenehexahydrobenzene, which on heating with

$$CH_3.CH\left\langle\begin{array}{l}CH_2\text{—}CH_2\\ CH_2\text{—}CH_2\end{array}\right\rangle C=CHBr$$

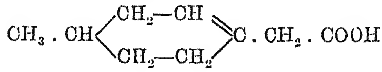
water forms hexahydro-*p*-tolualdehyde. Perkin and Pope[6] prepared their methylcyclohexylideneacetic acid by eliminating the elements of hydrogen bromide from α-bromohexahydro-*p*-tolylacetic acid, and, as shown by Rupe,

$$CH_3.CH\left\langle\begin{array}{l}CH_2\text{—}CH_2\\ CH_2\text{—}CH_2\end{array}\right\rangle CH-CHBr\text{—}COOH$$

Roners, and Lotz,[7] both $\alpha\beta$ and $\beta\gamma$-unsaturated acids are formed by loss of hydrogen bromide from α-bromo acids. Marckwald and Meth suggest that

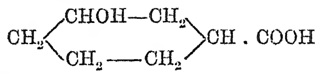
[1] Bouveault und Chereau, *Compt. rend.*, 1906, **142**, 1086.
[2] Knoevenagel and Schwartz, *Ber.*, 1906, **39**, 3441.
[3] *Ber.*, 1906, **39**, 2035.
[4] *Reports* 1906, p. 264.
[5] Marckwald and Meth, *Ber.*, 1906, **39**, 2404.
[6] *Proc. C. S.*, **22**, 107.
[7] *Ber.*, 1902, **35**, 4265.

Perkin and Pope's acid is 1-methyl Δ^3-tetrahydrobenzeneacetic acid, and

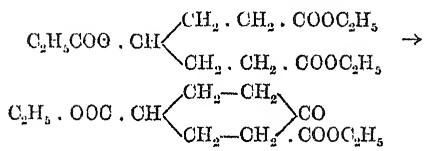


that the methylcyclohexylideneacetic acid, which would be produced at the same time, was overlooked on account of its extreme solubility in all organic solvents.

m-Hydroxybenzoic acid can be readily reduced by sodium and alcohol [1] to form cyclohexanol-3-carboxylic acid, which exists in well-defined *cis* and



trans modifications. When oxidised with chromic acid it is converted into cyclohexanone-3-carboxylic acid, the ethyl salt of which has been used as the starting point in the synthetical preparation of carvestrene. The method of preparing δ-ketohexahydrobenzoic acid from pentane-$\alpha\gamma\epsilon$-tricarboxylic acid is very laborious, and a decided improvement has now been introduced [2] by heating the ethyl ester of the above acid with sodium, when ethyl cyclohexanone-2 : 4-dicarboxylate is formed, which, when



digested with dilute sulphuric acid, is readily decomposed with formation of δ-ketohexahydrobenzoic acid, carbon dioxide, and ethyl alcohol.

Confirmation of the formulæ assigned by Baeyer [3] to the different forms of dihydrophthalic acids has been furnished through the resolution of *trans*-$\Delta^{3:5}$-dihydrophthalic acid [4] into two active isomerides by crystallising the strychnine hydrogen salt, the isomerides having $[\alpha]_D$ 126°. Baeyer stated that when treated with caustic soda the *trans* $\Delta^{3:5}$ acid was converted into the $\Delta^{2:6}$-variety; and with acetic anhydride it passed the *cis* $\Delta^{3:5}$ modification. As neither of these forms contains an asymmetric carbon atom, the optical activity ought to be destroyed by treatment with these reagents. This takes place in both cases, the change from one modification to the other proving to be a unimolecular reaction under the conditions of experiment.

A comparison of the electrical conductivities of α- and β-naphthoic, benzoic, and phthalic acids with their hydrogenised derivatives leads Abati [5] to the conclusion that, apart from the strongly negative character of the aromatic nucleus, the presence and position of double bonds in these acids has an undoubted influence on their conductivities, which is increased by a double bond in the $\alpha\alpha$ or $\beta\gamma$ positions, whereas if in the $\alpha\beta$ or $\gamma\delta$ positions practically the same value is obtained as for the corresponding saturated acids. The author considers this to be contrary to the declarations of Fichter and Pfister, [6] and does not consider that

[1] Perkin and Tattersall, *J.C.S.*, 1907, **91**, 480.
[2] Kay and Perkin, *ibid.*, 1906, **89**, 1640.
[3] *Annalen*, 1892, **269**, 145.
[4] Neville, *J.C.S.*, 1906, **89**, 1744.
[5] *Cent. Blatt.*, 1907, **1**, 886.
[6] *Annalen*, 1904, **334**, 201.

constitutional formulæ should be assigned from the results of single reactions, as has been done by Perkin and Pickles[1] in the case of the tetrahydroisophthalic acids. Abati and Minerva[2] have isolated hydrophthalic acids by the reduction of phthalic acid with sodium amalgam, and give the principal properties of these acids and their anhydrides.

Steric Hindrance in the Formation of Rings.—The interaction of the 1 : 4-dibromides and primary aromatic amines has been previously shown by Scholtz[3] to take place in one or two ways, according as to whether the primary amine contains a substituting group in the ortho position or not. Thus with *o*-xylylene dibromide and aniline or *m*- and *p*-toluidine a five-ring compound, is formed :—

$$C_6H_4\langle{}^{CH_2Br}_{CH_2Br} + H_2N.C_6H_5 = C_6H_4\langle{}^{CH_2}_{CH_2}\rangle N.C_6H_5 + 2HBr,$$

whereas when *o*-toluidine is used an open chain substance results :—

$$C_6H_4\langle{}^{CH_2Br}_{CH_2Br} + 2H_2N.C_6H_4.CH_3. = C_6H_4\langle{}^{CH_2.NH.C_6H_4.CH_3}_{CH_2.NH.C_6H_4.CH_3} + 2HBr.$$

The reaction has now been extended to the formation of six-ring systems,[4] where the condensation of numerous substances has shown that exactly similar conditions hold good: for *o*-toluidine condenses with pentamethylene dibromide to give pentamethylene-di-*o*-toluidine, $(CH_2)_5.(NH.C_6H_4.CH_3)_2$, whereas with *m*- or *p*-toluidine there is formed *m*- or *p*-tolylpiperidine.

$$CH_2\langle{}^{CH_2-CH_2}_{CH_2-CH_2}\rangle N.C_6H_4.CH_3.$$

Optical Influence of Conjugated Unsaturated Groups.—Kay and Perkin[5] have shown that the magnetic rotation of *d*-limonene differs from that of $\Delta^{3,8(9)}$-*p*-menthadiene, of which the value is abnormally high, and they expressed the belief that this was due to the presence of two conjugated double bonds. Bruhl[6] points out that this is correct, and that the high value could have been predicted with certainty, for Bruhl's previous work has proved that the numbers for the magnetic rotations and refractive values of substances are always largely increased by the presence of conjugated double linkings, not only C : C . C : C but also C : C . C : O. Only benzene derivatives, which contain monovalent atoms or groups substituting hydrogen atoms of the ring, give normal values, and here it is presumed that the three double bonds mutually neutralise one another. As soon as the symmetry of the six carbon atoms is disturbed by the introduction of CH_2 between the members of the ring, or by coupling the ring with other unsaturated groups, such as C : C, C : O, NO_2, &c., then the characteristic increase in value due to the conjugated bonds is shown.

Velocity of Chemical Change in the Polymethylene Series.—The following may be quoted as some of the more important general results of the

[1] *J.C.S.*, 1905, **87**, 293. [2] *Cent. Blatt.*, 1907, **1**, 887.
[3] *Ber.*, 1898, **31**, 414, 627, 1154, 1707; and 1899, **32**, 848.
[4] Scholtz, *Ber.*, 1907, **40**, 852. [5] *J.C.S.*, 1906, **89**, 839.
[6] *J.C.S.*, 1907, **91**, 115. See also *Ber.*, 1907, **40**, 878.

study of polymethylene derivatives in respect to the velocity of chemical change.[1]

The formation of the closed polymethylene ring from an open chain of normal structure proceeds with increase of velocity, the maximum occurring in the formation of the pentamethylene ring, decreasing through the hexamethylene, to the minimum increase in the case of the heptamethylene ring. The increase of velocity at the closing of the open chain is not a specific property of the polymethylene ring, but is observed in the formation of all rings, alicyclic and heterocyclic. The secondary polymethylene alcohols, in which the hydroxyl group is attached to the carbon atom of the ring, are typical secondary alcohols. Their esterification constants are higher than those of the normal saturated secondary alcohols; derivatives of cyclopentanol giving the highest, cyclohexanol much lower, and cycloheptanol the lowest values. The esterification constants of polymethylene tertiary alcohols are very low, but esterification proceeds regularly. This is characteristic of phenols, and does not occur with saturated tertiary alcohols. When side chains are present in the ortho or diortho positions a great decrease in the esterification constants is observed, an effect commonly ascribed to the benzene ring alone, but in reality a general property of all chains. Side chains in positions 3 or 4 of the polymethylene series produce an increase of the constants; and as open chain compounds show no such increase of velocity, this provides an important characteristic of closed chains. When a hexamethylene ring is introduced into the open chain of an alcohol, the decrease of the esterification constants is much larger than is effected by the benzene ring.

[1] Menschutkin, *J.C.S.*, 1906, **89**, 1532.

Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee, consisting of Sir H. E. ROSCOE (*Chairman*), Dr. MARSHALL WATTS (*Secretary*), Sir NORMAN LOCKYER, Professor Sir JAMES DEWAR, Professor G. D. LIVEING, Professor A. SCHUSTER, Professor W. N. HARTLEY, Professor WOLCOTT GIBBS, Sir W. DE W. ABNEY, *and* Dr. W. E. ADENEY.

STANDARD LINES.

Buisson and Fabry, 'C.R.,' cxliii. p. 165 (1906); cxliv. p. 1155 (1907).
Perot and Fabry, 'C.R.,' cxxxiii. p. 153 (1901).
Kayser, 'Ann. d. Physik' (4), iii. p. 195 (1900).
Eversheim, 'Zeitschrift für wissenschaftliche Photographie,' v. 152 (1907).
Wave-lengths in dry air at 15° C. and 760 mm.

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
6494·994			6495·209
	6471·666 Ca		71·885
30·859			31·063
	08·027 Fe		08·231
6393·612			6393·818
35·342	6335·346		35·550
	22·706 Fe		22·912
18·029			18·242
6265·147			6265·347
30·732	6230·746		30·946
6191·569			6191·770
	6151·639		51·834
37·700			
6065·493	6065·506		6065·708
27·059			27·265
	16·650 Mn		16·856
03·039			03·245
	5987·081 Fe		5987·286
5952·739			
34·683	34·666		34·883
5892·882 Ni			5893·098
	5862·368 Fe		62·580
57·760 Ni			
05·211 Ni			05·448
5763·013	5763·004		5763·215
60·843 Ni			
	15·095		15·309
09·396			09·616
5658·835			
15·658			5615·879

Note.—The wave-lengths now given by Buisson and Fabry rest on the value 6438·4696, determined by Benoit, Fabry, and Perot for the red line of Cadmium, and those of Perot and Fabry on Michelson's value 5085·8240 for the Cadmium green line.

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
5586·770	5586·778		5586·991
69·632			69·848
35·418			
06·783	06·794		07·000
5497·521	5497·536		5497·731
55·621			55·826
34·530	34·544		34·742
	09·800 Cr		10·000
05·780			05·987
5371·498			5371·686
	5367·485 Fe		67·670
	45·820		45·991
24·196			24·373
02·316			
5266·568			5266·729
	5247·587		47·737
	47·063		47·259
32·958*			33·124
5192·362			
	5171·622 Fe		5171·783
67·492			67·686
27·364			27·530
	23·739		23·889
10·415			10·570
	5090·787 Fe		5090·959
5083·343			
49·827			50·008
12·072			
01·880	01·881		02·044
4966·104			
	4923·943 Fe		4924·109
19·006			19·183
03·324			03·488
4878·226			
59·756†	4859·758		4859·934
23·521 Mn			23·697
4789·657			
	4783·449		4783·601
54·046 Mn			54·226
36·785	36·800		36·963
07·287			
	04·960		05·131
4678·855			4679·028
74·437			
	4643·483		43·645
02·944			
4592·658			
47·854			
31·155			
4494·572‡		4494·755	4494·735 (·756 in arc)
		89·929	
		84·420	
		76·207	
		69·566	
66·554		66·737	

* Eversheim, 5232·9630. † *Idem*, 4859·7613.
‡ *Idem*, 4494·5812.

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		4461·838	
		54·572	
		47·907	4447·899 (·912 in arc)
		42·522	
		30·801	
4427·314		27·490	
		15·301	15·299 (·298 in arc)
		04·929	04·927 (·928 in arc)
		4391·137	4391·149
		83·724	83·721
4375·935*		76·104	76·103 (·108 in arc)
		69·954	69·948 (in arc)
		67·759	
		58·689	
52·741		52·910	52·908
		46·739	
		37·219	
		25·941	25·932
15·089		15·255	
		09·542	
		4299·420	
		94·290	
		91·631	
		85·614	
4282·407†		82·567	
		71·933	4271·920
		71·333	
		60·656	60·647
		50·948	50·949
		50·299	50·300
		47·604	
		45·423	
		38·980	
		36·118	
33·615		33·771	
		27·606	
		22·387	22·396
		19·523	
		10·521	
		02·195	02·187
		4199·256	4199·257
4191·441		91·611	
		87·221	
		81·918	
		75·799	
		71·069	
		54·662	
47·677			
		44·033	
		37·156	
34·685			
18·552		18·709	
		14·608	14·600 (in sun)
		07·646	
		4098·346	
		96·135	

* Eversheim, 4375·9435. † *Idem*, 4282·4125.

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		4084·166	
		79·999	
4076·641			
		71·901	4071·903
		68·138	
		63·755	63·755
		62·605	62·602 (in sun)
		55·706	55·701 (,,)
		45·978	45·975
		44·776	
		32·796	
		30·670	
21·872		22·029	
		17·303	
		07·429	
		3998·211	
		96·148	
		86·330	
		84·112	
3977·745		77·892	3977·891 (in sun)
		69·411	
		66·219	
		56·823	
		56·610	
		48·927	
		45·269	
		41·032	41·034
35·818		35·966	
		28·073	28·060
		23·050	
		20·404	
		18·467	
		16·880	16·886
		13·784	
		09·980	
06·481		06·624	
		03·097	
		3899·853	
		95·801	
		93·538	
		87·193	
		86·426	3886·421
		78·722	
		78·166	
		72·640	
3865·526		65·670	
		60·054	60·050
		56·515	56·517 (in sun)
		50·114	
43·261			
		41·194	
		40·586	40·589
		34·370	
		33·463	
		27·967	27·973
		26·028	26·024
		24·591	
		20·573	20·566

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		3815·987	3815·984
		13·202	
		06·847	
3805·346			05·487
		01·822	
		3799·694	3799·698
		98·656	98·662
		95·149	95·150
		90·242	
		88·031	88·032
		78·670	
		76·606	
		70·452	
		67·339	67·344
		63·940	63·942
		58·381	58·379
3753·615			
		49·634	49·633
		48·409	48·409
		45·710	45·701
		43·510	43·502
		37·278	37·282
		35·016	35·075
		33·470	33·467
		32·541	32·542
		31·102	
		27·769	27·763
24·346		24·527	
		22·710	22·691
		20·083	20·086
		09·395	09·397
		07·199	07·186
		05·714	05·711
		02·180	
		3695·202	3695·194
		87·609	87·607
		83·205	83·202
		80·062	80·064
3677·628			
		76·461	
		69·674	
		59·673	
		55·625	
		51·615	
		50·429	
		47·997	47·995
40·391		40·541	40·536
		32·195	
		31·617	31·619
		30·506	
		22·158	22·147
		18·918	18·924
		17·944	17·920
		17·474	
		12·242	12·217
		09·011	09·015

STANDARD LINES—*continued*.

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
3606·681		3606·836	3606·831
		05·619	05·635
		3599·781	
		94·767	
		87·137	
		85·478	
		81·348	3581·344
		70·257	70·225
		65·535	65·528
		58·672	58·670
3556·879			
		53·898	
		45·793	
		40·287	40·266
		36·694	
		29·960	
		26·822	
		26·196	
		21·415	21·404
13·820		13·974	13·947
		08·663	
		08·627	
		06·650	
		00·716	00·721
		3497·989	3497·991
		90·721	90·721
3485·344		85·496	
		83·159	
		76·850	76·831
		75·600	75·594
		71·497	
		71·413	
		66·006	65·991
		60·067	
		58·454	
		50·484	
45·155		45·301	
		44·025	44·032
		41·138	41·135
		40·762	40·759
		27·263	27·282 (3427·279 in arc)
		24·430	
		18·649	
		13·275	
		06·938	06·955
		06·578	06·581
3399·337		3399·468	
		97·117	
		94·721	
		89·882	3389·887
		84·113	
		80·242	
		78·814	
70·789			
		67·675	
		66·993	
		66·917	
		55·355	

STANDARD LINES—*continued.*

Buisson and Fabry, Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		3351·882	3351·877
		48·056	48·011
		42·340	
		42·034	
		37·793	
		28·992	
		25·589	
3323·739			
		17·251	
		14·868	
		06·479	06·471
		06·106	06·117
		3298·263	
		92·721	
		86·884	
		84·720	
		80·386	
3271·003		71·129	
		65·746	
		57·724	
		53·043	
		48·332	
		46·617	
		44·308	
		39·564	
		31·091	
		28·379	
25·790		25·905	3225·923
		22·187	22·203
		16·057	
		14·158	14·152 (in arc)
		12·112	
		10·953	
		05·513	
		00·595	
		3199·638	
		93·423	
		92·921	
		91·778	
		88·947	
		85·015	
		78·122	
3175·447		75·556	
		71·743	
		66·551	
		65·129	
		62·064	
		60·764	
		57·157	
		51·460	
		44·096	
		42·565	
		40·503	
		32·627	
25·661		25·770	
		19·609	
		16·747	
		12·183	

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		3100·778	3100·779 (in arc)
		00·418	00·415 „
		00·057	00·064 „
		3095·013	3095·003
		91·687	
		83·853	83·849 (in arc)
		75·830	75·849 „
		68·286	
		67·363	67·363 (in arc)
		64·042	
		59·202	59·200 (in arc)
		57·562	57·557 „
		51·179	
		47·719	47·720 (in arc)
		41·860	
		41·753	
		37·505	37·492
		31·753	
3030·152			
		25·960	25·958 (in arc)
		24·153	24·154 „
		21·194	21·191 „
		20·764	20·759 „
		20·619	20·611 „
		19·105	19·
		17·747	17·747 (in arc)
		16·305	16·296 „
		09·690	09·696 „
		08·254	08·255 „
		07·409	07·408 „
		07·262	07·260 „
		01·068	01·070 „
		2999·630	2999·632 „
		94·554	94·547 „
		90·511	
2987·293		87·410	87·410 (in arc)
		83·690	83·689 „
		81·565	81·570 „
		76·253	
		73·366	73·358 (in arc)
		73·254	73·254 „
		70·227	70·233 „
		67·019	67·016 „
		65·379	65·381 „
		57·484	57·485 „
		54·061	54·058 „
		48·557	
		47·996	47·993 (in arc)
41·347		41·462	
		37·030	37·020 (in arc)
		29·119	29·127 „
		26·699	
		23·409	
		18·144	
12·157		12·273	12·275 (in arc)
		07·630	
		01·496	
		2899·531	

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		2894·617	
		90·000	
		87·920	
		80·867	
		77·414	
2874·176		74·284	
		69·418	
		63·973	
		59·007	
51·800		51·910	2851·904
		48·828	
		44·083	44·085 (in arc)
		43·742	43·744 ,,
		38·231	38·226 ,,
		35·562	
		32·543	32·545 (in arc)
		25·803	
		25·660	25·667 (in arc)
		23·382	23·389 ,,
		17·612	
13·290		13·391	13·388 (in arc)
		07·088	
		04·622	
		2797·877	
		91·989	
		88·207	2788·201 (in arc)
		81·936	81·945 ,,
2778·225		78·327	78·340 ,,
		72·205	72·206 ,,
		68·621	68·630 ,,
		62·125	62·110 ,,
		61·883	61·876 ,,
		57·413	
		56·412	56·427 (in arc)
		55·834	55·837 ,,
		50·238	50·237 ,,
		47·080	
		46·580	
		45·177	
		44·624	
		44·163	
		42·506	42·485 ,,
		42·349	
39·550		39·639	
		37·407	37·405 (in arc)
		35·566	
		33·978	33·973 ,,
		30·832	
		28·914	
		25·024	
		23·671	23·668 (in arc)
		20·997	20·989 ,,
		19·121	19·119 ,,
		18·530	
14·419		14·503	
		08·663	
		06·672	06·684 (in arc)
		2699·193	

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		2690·153	
		89·302	
		80·544	
2679·065		79·148	2679·148 (in arc)
		73·315	
		69·581	
		66·897	
		56·232	
		51·800	
		47·649	
		44·085	
		35·899	
		31·139	31·125 (in arc)
28·296		28·383	
		25·754	
		23·627	
		20·499	
		18·108	
		17·706	
		13·914	
		11·963	11·965 (in arc)
		07·155	
		06·920	
		2599·663	
		99·483	2599·494 (in arc)
		98·456	98·460 ,,
2588·016		88·102	
		85·964	
		84·623	84·629 (in arc)
		82·408	
		78·012	
		75·845	
		74·462	
		67·001	
62·541		62·619	
		56·963	
		51·192	
		49·708	49·704 (in arc)
		46·072	46·068 ,,
		44·016	
		42·192	
		41·064	41·058 (in arc)
		37·263	
		35·699	35·648 ,,
		33·911	
		29·928	
		29·223	
28·516 Si			28·599 Si
		27·525	27·530 ,,
		24·393	
		23·754	
		22·950	22·948 (in arc)
		18·198	18·188 ,,
		17·754	
		11·857	
		10·927	10·934 (in arc)
		[07·991	
06·904 Si			06·944 Si

STANDARD LINES—*continued.*

Buisson and Fabry Iron Arc	Perot and Fabry Solar Spectrum	Kayser Iron Arc	Previous Measurements (Solar Spectrum) Rowland
		2501·228	2501·223 (in arc)
		2496·625	
		93·331	
		91·249	2491·244 (in arc)
		90·737	90·723 ,,
		89·844	89·838 ,,
		88·232	88·238 ,,
		87·155	
		84·280	84·283 (in arc)
		83·618	
		83·361	83·359 ,,
		79·872	79·871 ,,
		74·906	
		72·976	72·974 (in arc)
		72·436	
		68·974	
		65·244	
		62·740	62·743 (in arc)
		62·279	
		57·686	57·680 (in arc)
		53·568	
		47·808	47·785 (in arc)
		42·658	
		40·201	
		39·834	
		38·274	
2435·159 Si			
		31·126	
		24·231	
13·310		13·393	
		11·152	
		10·601	10·604 (in arc)
		06·742	06·743 ,,
		04·969	04·971 ,,
		04·519	
		2399·322	2399·328 (in arc)
		95·709	95·715 ,,
		90·058	
		88·711	88·710 (in arc)
		84·473	
		83·324	
		82·114	82·122 (in arc)
		80·840	
		79·355	
		75·273	
2373·737		73·813	73·771 (in arc)
		68·670	
		64·904	64·897
		59·187	
		54·969	
		48·380	48·385 (in arc)
		48·196	
		43·567	43·571 (in arc)
		32·869	
		31·384	
		27·468	

Iridium.

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Kayser, 'Abhandl. königl. Wissensch. Berlin,' 1897.

Exner and Haschek, 'Wellenlängen-Tabellen der Bogenspektren der Elemente,' Leipzig und Wien, 1904.

Lohse, 'Astrophys. Obs. Potsdam,' xii. (1902).

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Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5894·324		2			1·61	4·6	16960·9
5625·772		3			1·53	4·8	17770·5
20·266		1			"	"	88·0
5469·648		1			1·49	5·0	18277·7
54·724		2			"	"	18324·4
49·716		4			"	"	44·6
5364·507		2			1·47	5·1	18656·0
57·081		0			1·46	"	61·8
40·932		1			"	"	18718·2
5239·091		1			1·43	5·2	19082·1
5178·128		1			1·42	5·3	19306·7
5050·001		0			1·38	5·4	19796·6
46·227		0			"	"	19811·4
09·323		0			1·37	5·5	19957·3
02·874		1			"	"	83·0
4999·898		2			"	"	94·9
70·629		0			1·36	"	20112·7
39·311		0			1·35	5·6	20240·1
38·225		1			"	"	44·6
4845·539		0			1·33	5·7	20631·8
40·934		2			1·32	"	51·5
09·636		2			"	"	20785·9
07·302		0			"	"	96·0
4795·827		3			1·31	"	20845·8
78·330		4			"	5·8	20922·0
58·107		2			1·30	"	21011·0
56·613		4			"	"	17·6
32·014		1			"	"	21126·8
29·005		4			1·29	"	40·3
09·034		2			"	"	21230·0
02·751		0			"	5·9	58·2
			4696·0	1	"	"	21289·
			94·0	1	"	"	98·
			92·7	1	1·28	"	21304·
			83·8	1	"	"	44·
			83·0	1	"	"	48·
			81·5	1	"	"	55·
			78·6	1	"	"	68·
			74·2	1n	"	"	89·
			73·4	1n	"	"	92·
			72·0	1n	"	"	98·
			71·4	1n	"	"	21401·
			69·7	1n	"	"	09·
			69·4	1n	"	"	10·
4669·130		2			"	"	11·4

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ +	1/λ −	
			4665·0	1n	1·28	5·9	21430·
			56·5	1	,,	,,	69·
4656·329		4			,,	,,	70·2
			55·9	1n	,,	,,	72·
			55·4	1n	,,	,,	74·
			54·9	1n	1·27	,,	77·
			54·4	1n	,,	,,	79·
			50·7	1	,,	,,	96·
40·231		2	40·3	1n	,,	,,	21544·8
		2	27·5	1n	,,	6·0	21604·
16·549	4616·55	4	16·6	2	1·26	,,	21655·2
14·342		0			,,	,,	65·6
			04·7	1	,,	,,	21711·
			4586·5	1n	,,	,,	97·
			85·7	1n	,,	,,	21801·
			84·5	1n	,,	,,	07·
			82·0	1	,,	,,	19·
			79·5	1n	1·25	,,	30·
			70·5	1n	,,	,,	73·
4570·183		2	70·1	1	,,	,,	75·0
68·246	4568·30	3n	68·2	2	,,	,,	84·1
			65·0	1n	,,	6·1	21900·
			64·2	1	,,	,,	04·
			61·0	1	,,	,,	19·
			58·7	1	,,	,,	30·
			58·0	1	,,	,,	33·
	54·72	1	54·7	1	,,	,,	49·1
			54·2	1	,,	,,	52·
			52·5	1n	,,	,,	60·
50·941		2	50·9	1	,,	,,	67·4
48·645	48·64	3n	48·7	2	,,	,,	78·5
45·837	45·84	3	45·8	2	,,	,,	92·0
			43·0	1	1·24	,,	22006·
			42·4	1	,,	,,	09·
			39·3	1	,,	,,	24·
38·819		1	38·7	1	,,	,,	26·1
			34·5	1b	,,	,,	47·
33·003		2	33·0	1	,,	,,	54·3
			15·3	1n	,,	,,	22141·
			14·4	1n	,,	,,	45·
			12·0	1	,,	,,	57·
			11·0	1b	,,	,,	62·
			09·0	1n	,,	,,	72·
			05·7	1n	1·23	,,	88·
			05·1	1n	,,	,,	91·
			01·7	1n	,,	,,	22208·
			01·0	1n	,,	,,	11·
4496·200		1	4496·1	1	,,	6·2	34·8
95·525	4495·52	2	95·4	2	,,	,,	38·2
92·333		1	92·3	1	,,	,,	53·9
91·523		2	91·4	2	,,	,,	58·0
			84·0	1n	,,	,,	95·
			82·1	1	,,	,,	22305·
78·649	78·65	3	78·4	4	,,	,,	22·0
			70·5	1n	,,	,,	63·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			4467·4	1b	1·22	6·2	22378·
			66·8	1	,,	,,	81·
			60·0	1	,,	,,	22415·
			58·2	1	,,	,,	24·
4452·987		1	52·9	1	,,	,,	50·6
			52·7	1n	,,	,,	52·
			51·4	1	,,	,,	59·
			50·9	1	,,	,,	61·
	4450·41	1n			,,	,,	63·6
50·346		2	50·2	1	,,	,,	63·9
49·540		0			,,	,,	68·0
			44·0	1n	,,	,,	96·
			43·1	1	,,	,,	22501·
26·459	26·45	5	26·5	4	1·21	6·3	85·1
25·936		0			,,	,,	87·8
22·121		1	22·0	1	,,	,,	22607·3
			21·3″	1n	,,	,,	12·
11·344		2	11·2	1	,,	,,	62·5
			10·5	1	,,	,,	67·
06·926		0	06·9	1	,,	,,	85·3
03·952	03·98	3	04·0	2	,,	,,	22700·5
			01·4	1	,,	,,	14·
4399·645	4399·68	4	399·7	6	,,	,,	22·7
92·758	92·80	2	92·8	1	1·20	,,	58·3
			90·4	1n	,,	,,	71·
			88·5	1	,,	,,	81·
			88·1	1	,,	,,	83·
			81·2	1n	,,	,,	22819·9
80·930		[illegible]	80·4	1	,,	,,	23·
			80·0	1	,,	,,	25·
77·175		3	77·2	1	,,	,,	39·6
76·575		0	76·6	1	,,	,,	42·6
			74·9	1	,,	,,	51·
			73·8	1n	,,	,,	57·
			73·0	1n	,,	,,	61·
			72·3	1	,,	,,	65·
			72·0	1n	,,	,,	67·
			69·2	1n	,,	,,	81·
62·289		1			,,	6·4	22917·3
			61·3	1	,,	,,	23·
			60·9	1	,,	,,	25·
			60·2	1	,,	,,	29·
			59·6	1	,,	,,	32·
			58·4″	1n	,,	,,	38·
			55·8	1n	1·19	,,	52·
			54·3	1n	,,	,,	59·
			53·5	1	,,	,,	64·
52·720		2	52·7	1	,,	,,	67·7
51·462		1			,,	,,	74·4
			48·1	1n	,,	,,	92·
			43·7	1b	,,	,,	23016·
			42·2	1n	,,	,,	23·
			39·6	1b	,,	,,	37·
32·490		0			,,	,,	75·0
30·060		0	30·0	1	,,	,,	88·0

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
			4328·8	1b	1·19	6·4	23095·
			24·7	1	,,	,,	23117·
4316·456		1	16·6	1	1·18	,,	60·7
			14·0	1n	,,	,,	74·
			13·2	1	,,	,,	78·
11·669	4311·68	4	11·7	6	,,	,,	86·4
			11·5	2	,,	,,	87·
10·750	10·76	3			,,	,,	91·4
			08·3	1	,,	6·5	23205·
	06·10	1	06·2	1	,,	,,	16·4
05·359		0	05·4	1	,,	,,	20·4
01·776	01·79	3	01·8	4	,,	,,	39·7
00·802		1	00·9	1	,,	,,	45·0
			4297·7	1	,,	,,	62·
			95·8	1	,,	,,	72·
4286·776	4286·79	1	86·7	1	,,	,,	23321·0
			86·0	1n	,,	,,	25·
			86·2″	1n	,,	,,	24·
			79·0	1	1·17	,,	63·
			76·7	1b	,,	,,	76·
			74·8	1	,,	,,	86·
69·101		0	69·0	1	,,	,,	23417·6
68·251	68·25	5	68·3	6	,,	,,	22·3
66·532		0	66·5	1n	,,	,,	31·7
65·450	65·47	1n			,,	,,	37·6
			65·3	1	,,	,,	39·
62·051		0	62·0	1	,,	,,	56·4
61·408		2	61·3	1	,,	,,	59·9
			60·2	1	,,	,,	67·
59·280	59·26	3	59·2	2	,,	,,	71·7
57·528		2	57·5	1	,,	,,	81·3
			49·0	1n	,,	6·6	23528·
			47·5	1	,,	,,	37·
			47·2	1	,,	,,	38·
43·944		0			1·16	,,	56·4
41·198		0			,,	,,	71·6
40·644		0			,,	,,	74·7
30·486		0			,,	,,	23631·3
			27·6	1	,,	,,	48·
			26·9	1	,,	,,	51·
			25·5	1	,,	,,	59·
23·327		0			,,	,,	71·4
			22·2	1n	,,	,,	78·
			21·5	1	,,	,,	82·
	21·25	1			,,	,,	83·1
20·950		2	20·8	1	,,	,,	84·7
			18·9	1	,,	,,	96·
18·428		1	18·3	1	,,	,,	98·9
18·243		0			,,	,,	99·9
17·908		2	17·8	1	,,	,,	23701·8
			15·2	1n	,,	,,	17·
			14·6	1	,,	,,	20·
			13·4	1	,,	,,	27·
			12·6	1	,,	,,	32·
12·383		2			,,	,,	32·9

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4212·197		0	4212·1	1	1·16	6·6	23734·0
			11·2	1	,,	,,	40·
			10·7	1b	,,	,,	42·
			09·7	1	,,	,,	48·
			06·7	1b	,,	,,	65·
			02·5	1b Fe ?	1·15	,,	89·
00·031	4200·07	2	00·1	1	,,	6·7	23802·7
			4197·8	1	,,	,,	15·
			95·8	1b	,,	,,	27·
			93·0	1	,,	,,	43·
			83·4	2	,,	,,	97·
4182·626	4182·62	1n	82·7	2	,,	,,	23901·7
			81·8	1n	,,	,,	06·
72·736	72·81	2	72·8	2	,,	,,	57·2
			66·9	1	1·14	,,	92·
66·224	66·22	3	66·3	2	,,	,,	95·9
			65·3	1	,,	,,	24001·
			63·8	1	,,	,,	10·
			63·5	1	,,	,,	12·
			62·3	1n	,,	,,	18·
			61·7	1n	,,	,,	22·
			61·1	1n	,,	,,	25·
			58·2	1	,,	,,	42·
	55·90	1n	55·8	2	,,	,,	55·5
			51·4	1	,,	,,	82·
			39·3	1	,,	6·8	24152·
			38·3	1	,,	,,	58·
			37·8	1	,,	,,	61·
			36·5	1b	,,	,,	68·
			29·6	1	1·13	,,	24209·
			29·2	1	,,	,,	11·
			28·5	1	,,	,,	15·
			28·0	1	,,	,,	18·
			27·6	1	,,	,,	20·
			26·6	1	,,	,,	26·
			26·2	1	,,	,,	29·
			23·2	1n	,,	,,	46·
			17·5	1	,,	,,	80·
			16·7	1	,,	,,	84·
			16·4	1	,,	,,	86·
15·957	15·95	3	15·8	4	,,	,,	88·9
			13·8	1	,,	,,	24302·
			10·3	1n	,,	,,	22·
			08·4	1	,,	,,	34·
			08·3	1n	,,	,,	34·
			07·8	1	,,	,,	37·
	04·35	1			,,	,,	57·6
			00·3	1n	,,	,,	82·
4092·767	4092·79	2	4092·6	4	1·12	6·9	24426·4
			91·6	1n	,,	,,	33·
			90·3	1b	,,	,,	41·
			89·6	1	,,	,,	45·
			86·0	1	,,	,,	67·
82·542		1	82·6	1	,,	,,	87·6
			82·3	1	,,	,,	89·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4081·564		0	4081·5	1	1·12	6·9	24493·5
80·737	4080·75	2	80·6	1	,,	,,	98·5
			78·2	1	,,	,,	24514·
75·774	75·76	2	75·7	1	,,	,,	28·4
72·532		2	72·4	2	,,	,,	47·8
70·822	70·88	2	70·7	2	,,	,,	57·9
70·067	70·10	3	70·0	6	,,	,,	62·6
			68·5	1	,,	,,	72·
			68·2	1	,,	,,	74·
			66·8	1b	,,	,,	82·
			65·0	1	,,	,,	93·
			64·4	1	,,	,,	97·
			62·5	1	,,	,,	24608·
			62·1	1	,,	,,	11·
59·377	59·43	1n	59·3	2	,,	,,	27·3
			59·2	1	,,	,,	28·
			56·9	1	,,	,,	42·
56·620	56·65	1n	56·5	2	,,	,,	44·1
55·833		0	55·7	1n	,,	,,	48·9
			55·4	1n	,,	,,	52·
			54·1	1n	1·11	,,	59·
			53·8	1n	,,	,,	61·
			53·2	1n	,,	,,	65·
			51·9	1	,,	,,	73·
51·538		0	51·5	1n	,,	,,	75·1
51·071		2	51·0	1	,,	7·0	77·8
	50·81	1n			,,	,,	79·4
48·782		0			,,	,,	91·8
			47·6	1	,,	,,	99·
			47·1	1	,,	,,	24702·
			46·6	1	,,	,,	05·
			45·2	1	,,	,,	14·
			44·0	1n	,,	,,	21·
			43·2	1n	,,	,,	26·
			41·4	2	,,	,,	37·
40·578		1			,,	,,	41·9
40·224	40·24	3	40·3	2	,,	,,	44·1
33·923	33·91	3	33·8	4	,,	,,	82·8
			32·2	1	,,	,,	93·
			31·6	1	,,	,,	97·
			31·0	1	,,	,,	24801·
			30·5	1	,,	,,	04·
			29·4	1n	,,	,,	11·
			25·5	1	,,	,,	35·
			22·1	1	,,	,,	56·
			21·6	1	,,	,,	59·
20·194	20·20	4			,,	,,	67·4
			20·0	6	,,	,,	69·
			16·6	1	,,	,,	90·
			15·7	1	1·10	,,	95·
			15·3	1	,,	,,	98·
			13·8	1	,,	,,	24907·
			11·6	1	,,	,,	21·
			11·3	1	,,	,,	23·
			09·0	1	,,	,,	37·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
			4008·5	1	1·10	7·0	24940·
			07·9	1	,,	,,	44·
			07·5	1	,,	,,	46·
			06·7	1	,,	,,	51·
			06·3	1	,,	,,	54·
4005·717		1	05·6	1	,,	,,	57·3
05·164	4005·19	1n	05·0	1	,,	,,	60·7
			02·0	1	,,	7·1	81·
			01·8	1n	,,	,,	82·
			00·6	1b	,,	,,	89·
			3999·0	1n	,,	,,	99·
3996·602		0	96·6	1	,,	,,	25014·2
			95·9	1	,,	,,	19·
92·277	3992·30	5	92·2	6	,,	,,	41·2
			90·5	1	,,	,,	53·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
3989·575		2					1·10	7·1	25058·2
			3989·2	1			,,	,,	61·
87·963		2	88·0	1			,,	,,	68·4
			87·5	1			,,	,,	71·
			86·5	1			,,	,,	78·
85·003		2	85·0	1			,,	,,	87·0
			84·1	1			,,	,,	93·
			83·7	1			,,	,,	95·
			81·2	1n			,,	,,	25111·
			80·0	1			,,	,,	19·
			79·6	1			,,	,,	21·
			79·3	1			,,	,,	23·
			78·9	1			,,	,,	26·
			78·6	1			,,	,,	27·
78·240		0	78·3	1			,,	,,	29·6
			77·0	1			,,	,,	37·
76·466	3976·49	5	76·5	6			,,	,,	40·8
			75·8	1			1·09	,,	45·
			75·5	1			,,	,,	47
			73·3	2			,,	,,	61·
			70·3	1			,,	,,	80·
					3969·35	0·3	,,	,,	85·9
			67·6	1			,,	,,	97·
			66·5	1	66·52		,,	,,	25203·9
			66·2	1			,,	,,	06·
			65·0	1			,,	,,	14·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		λ+	$\frac{1}{\lambda}$ −	
			3964·5	1			1·09	7·1	25217·
					3963·78	0·4	,,	,,	21·3
3962·926		2	63·0	1	63·00		,,	,,	26·5
					61·66	0·1	,,	,,	34·9
					61·24	0·1	,,	,,	37·5
			60·6	1	60·63	0·1n	,,	,,	41·4
					59·03	0·4	,,	,,	51·6
			56·8	1			,,	,,	66·
56·262		0					,,	7·2	69·2
					56·09	1·5b	,,	,,	70·3
					54·60	0·8b	,,	,,	79·8
		0	52·7	1	52·85	0·3n	,,	,,	91·0
52·099	3952·15	1	52·0	4	52·12	1·0	,,	,,	95·6
			52·1	1			,,	,,	
50·259		0			50·34	0·3n	,,	,,	25307·4
48·459	48·47	1n			49·42	0·1	,,	,,	13·0
					48·45	0·3	,,	,,	19·2
46·420	46·40	4	46·4	4	46·44	1·1	,,	,,	32·2
			45·7	1	45·74	0·6	,,	,,	37·6
					45·22	0·2n	,,	,,	39·9
44·534	44·52	1n	44·5	1	44·50	0·2	,,	,,	44·4
44·534	44·52	1n	44·5	1	44·50	0·2	,,	,,	44·4
			43·4	1			,,	,,	52·
					42·83	0·1	,,	,,	55·3
					42·15	0·1	,,	,,	59·7
41·242		0	41·2	1			,,	,,	66·
			38·5	1n	38·70	0·2	,,	,,	81·9
			37·8	1n			,,	,,	88·
			36·6	1n			1·08	,,	95·
35·005	34·99	3	35·0	4	35·00		,,	,,	25405·8
34·063		2u	34·0	2			,,	,,	11·8
			32·3	1			,,	,,	23·
31·903		0	32·0	1	31·93		,,	,,	25·7
					31·34	0·1	,,	,,	29·4
			29·0	1			,,	,,	45·
			28·6	1	28·55	0·1	,,	,,	47·5
					27·28	0·1	,,	,,	55·7
	26·05	1n	26·1	1	26·07	0·9	,,	,,	63·6
			25·5	1			,,	,,	67·
					25·35	0·1	,,	,,	68·2
24·573	24·55	1n	24·6	1	24·66	0·1	,,	,,	73·1
			24·1	1			,,	,,	76·
23·634	23·63	1	23·7	1	23·63	0·9	,,	,,	79·4
					23·10	0·3	,,	,,	82·8
			21·1	1	21·02	0·1	,,	,,	96·4
					19·25	1b	,,	,,	25507·9
			18·3	1			,,	,,	14·
			16·8	1			,,	,,	24·
15·538	15·53	3	15·6	6	15·53	1·8	,,	,,	32·1
15·055	15·06	1	15·1	1	15·08	0·2	,,	,,	35·1
			14·5	1	14·46	0·1	,,	,,	39·1
			14·0	1			,,	,,	42·
			13·4	1			,,	,,	46·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3912·6	1n	3912·23	0·6b	1·08	7·2	25553·7
			11·7	1			"	"	57·
			11·2	1			"	"	60·
			10·6	1			"	"	64·
			09·7	1			"	"	70·
3909·219		0			09·25	0·5	"	"	73·2
			07·6	1n	07·85	0·2b	"	7·3	82·2
			06·9	1n	06·5		"	"	89·7
			06·0	1			"	"	94·
					05·64	0·2	"	"	96·7
			04·3	1n	04·48	0·1n	"	"	25604·3
02·807	3902·78	2			02·97		"	"	15·0
02·632	02·65	4	02·7	8	02·68	2·0	"	"	16·3
			01·5	1n	01·82	0·1	"	"	21·8
					01·40	0·1	"	"	24·5
			01·0	1	00·95	0·2	"	"	27·5
			00·0	1n			"	"	34·
					3899·37	0·3	"	"	37·9
					99·06	0·1n	"	"	40·0
			3898·5	1n	98·57	0·1n	"	"	43·1
					97·99	0·1n	"	"	46·9
					97·40	0·1n	"	"	50·8
					96·61	0·1n	1·07	"	56·0
			95·6	6	95·73	3	"	"	61·8
					95·07	0·3n	"	"	66·2
			94·0	1n			"	"	68·
			94·0	1n	94·00	0·1n	"	"	73·2
					93·49	0·1n	"	"	76·6
			93·0	1n			"	"	80·
			92·2	1n	92·32	0·4	"	"	84·3
					92·14	0·4	"	"	85·5
					91·56	0·1	"	"	89·3
			90·3	1	90·39	0·1n	"	"	97·1
3889·715		0	89·6	1	89·72	0·2	"	"	25701·5
			89·1	1			"	"	06·
			87·5	1	87·88	0·1n	"	"	13·7
			86·0	1			"	"	26·
			85·5	1	85·58	0·1	"	"	28·9
			84·7	1	84·86	0·1n	"	"	33·6
			84·3	1n	84·29	0·1n	"	"	37·4
			83·3	1n			"	"	44·
			82·5	1n	82·44	0·6b	"	"	49·7
			81·0	1n			"	"	59·
					80·89	0·1n	"	"	60·0
			79·6	1			"	"	69·
					79·19	0·1n	"	"	71·3
			78·0	1			"	"	79·
					77·46	0·1n	"	"	82·8
			77·1	1			"	"	85·
					76·93	0·4	"	"	86·3
			75·5	1n	75·93	0·1b	"	"	93·0
			75·0	1			"	"	99·
			73·7	4	73·74	0·5b	"	"	25807·5

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		λ+	$\frac{1}{\lambda}-$	
	3873·28	2 Co ?	3873·3	4	3873·31	0·5	1·07	7·3	25810·5
			72·0	1	71·94	0·1n	,,	,,	19·5
			71·8	1			,,	,,	20·
			70·9	1			,,	,,	26·
					70·22	0·2n	,,	,,	31·0
			69·5	2	69·66	0·3	,,	,,	34·8
			69·0	1n			,,	,,	39·
			68·8	1			,,	,,	41·
	67·92	1			68·00	0·4	,,	,,	46·1
	65·75	3	65·7	6	65·78	1·0	,,	,,	60·8
					64·73	0·3n	,,	,,	67·7
			63·7	1n	63·68	0·1n	,,	,,	74·8
			63·1	1n			,,	,,	79·
					62·85	0·4	,,	,,	80·3
			62·2	4	62·16	0·5b	,,	,,	85·0
			62·1	1			,,	,,	85·
			61·5	1	61·44	0·2n	,,	,,	89·8
					60·84	0·1n	,,	,,	93·8
			56·8	1	57·71	1·2	,,	,,	25914·8
			56·7	4	56·62	0·5n	1·06	,,	22·1
			56·2	2	56·25	0·2	,,	,,	24·6
			54·8	1n	54·87	0·1n	,,	,,	33·9
					54·12	0·1n	,,	,,	39·0
			52·6	1n			,,	,,	49·
			50·8	1n			,,	,,	61·
					50·58	0·3n	,,	,,	62·8
			50·1	1n			,,	,,	66·
			49·0	1	49·00	0·4λ	,,	,,	73·5
			48·5″	1n	48·31	0·1n	,,	,,	78·1
			47·5	1	47·41	0·2n	,,	,,	84·2
					46·82	0·1n	,,	,,	88·2
			46·0	1	46·07	0·2n	,,	,,	93·3
			45·1	1	45·16	0·1n	,,	,,	99·4
			44·7	1			,,	,,	26003·
					43·05	0·2n	,,	,,	13·7
			42·8	1n			,,	,,	15·
			42·2	1			,,	,,	19·
			41·8	1			,,	,,	22·
			39·6	1			,,	,,	37·
			39·2	2n	39·15	0·5b	,,	,,	40·1
			37·7	2	37·86	0·1	,,	,,	48·9
					36·21	0·1n	,,	,,	60·1
			35·8	1			,,	,,	63·
			35·2	1	35·26	0·2n	,,	,,	66·5
			32·7	1	34·06	0·1	,,	,,	74·7
					32·47	0·1n	,,	,,	85·5
			31·9	1	31·74	0·5b	,,	,,	90·5
			31·6	1			,,	,,	91·
			30·5	2	30·48	0·4n	,,	,,	99·1
			29·8	1b			,,	,,	26104·
					28·61	0·2n	,,	,,	11·8
			27·1	1	27·05	0·2n	,,	,,	22·5
			26·0	1			,,	,,	30·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	3825·2	2b	3825·2	1n	3825·13	0·2n	1·06	7·3	26135·3
					24·62	0·4	,,	,,	39·1
			23·5	1	23·50	0·3n	,,	,,	46·7
					22·32	0·4	,,	,,	54·9
					21·58	0·1n	,,	,,	59·9
					20·99	0·1n	,,	,,	63·9
			20·0	1n	19·95	0·1n	,,	,,	71·0
					19·52	1n	,,	,,	74·0
			19·2	1n	19·19	0·3	,,	,,	76·3
					18·82	0·2	,,	,,	78·8
			18·6	1	18·33	0·1	,,	,,	82·2
3817·385	17·40	3	17·3	4	17·42	1·0	,,	7·4	88·4
					16·59	0·1n	1·05	,,	94·0
			15·7	1	15·70	0·2	,,	,,	26200·1
					15·10	0·1n	,,	,,	04·2
			14·7	1			,,	,,	07·
			14·5	1			,,	,,	08·
			13·8	1	13·91	0·2n	,,	,,	12·4
			13·0	1			,,	,,	19·
			12·8	1	12·89	0·5	,,	,,	19·4
					12·40	0·1n	,,	,,	22·8
			11·8	1			,,	,,	27·
			10·5	1	10·57	0·2b	,,	,,	35·4
			10·4	1			,,	,,	37·
			09·7	1	09·81	0·1n	,,	,,	40·6
			08·3	1n	08·83	0·2	,,	,,	47·4
			07·1	1	06·86	0·1n	,,	,,	61·0
			04·6	1	06·09	0·1n	,,	,,	66·3
	05·44	2n					,,	,,	70·8
			04·1	1	04·77	0·1n	,,	,,	75·4
					04·26	0·1	,,	,,	78·9
					03·80	0·4	,,	,,	82·1
					03·00	0·2	,,	,,	87·6
					02·53	0·2	,,	,,	90·9
00·243	00·25	10	00·2	8	00·29	2·0	,,	,,	26306·6
	3799·65	2n			3799·51	1·3	,,	,,	11·3
3799·047	99·05	3	3799·1	4	99·07	1·1	,,	,,	15·0
			98·2	1	98·18	0·4	,,	,,	20·0
			98·1	1	96·77	0·3	,,	,,	30·8
			96·3	1n			,,	,,	34·0
					95·97	0·2	,,	,,	36·3
					95·56	0·1	,,	,,	39·2
94·211	94·20	1	94·1	4	94·18	0·3	,,	,,	48·4
	93·95	2	93·9	4	93·95		,,	,,	50·3
					93·40		,,	,,	54·2
			91·6	2			,,	,,	67·
					90·67	1·0	,,	,,	73·2
					90·29	0·3	,,	,,	75·8
			89·6	1	89·67	0·2	,,	,,	80·1
					88·67	0·1n	,,	,,	87·3
			87·4	1			,,	,,	96·
			87·1	1	87·18	0·1n	,,	,,	97·5
			86·2	1	86·22	1·0s	,,	,,	26404·2

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
					3784·85	0·3n	1·05	7·4	26413·7
					84·35	0·1n	,,	,,	17·0
					82·37	0·9	,,	,,	31·0
			3781·5	1	81·33	0·3n	,,	,,	38·3
			79·8	1			,,	,,	49·
			79·2	1n			,,	,,	53·
					78·85	0·1	,,	,,	55·7
			77·7	1	77·73	0·5	,,	,,	63·5
					77·14	0·2	,,	,,	67·7
			75·3	1	75·32	0·1	1·04	,,	80·4
			74·5	1	74·59	0·2n	,,	,,	85·5
			74·0	1			,,	,,	90·
			71·8	1	71·76	0·2	,,	7·5	26505·3
	3770·89	1	70·9	1	70·86	0·2	,,	,,	11·5
			70·4	1			,,	,,	14·9
3768·817	68·83	1	68·8		68·84	0·4	,,	,,	25·9
			66·6	1	67·48	0·4	,,	,,	35·4
					66·59	0·1b	,,	,,	41·7
			66·3	1			,,	,,	54·
					62·40	0·3n	,,	,,	71·3
			62·1	1	62·11	0·6	,,	,,	73·3
			61·8	1	61·68	0·5	,,	,,	76·4
	59·64	1			60·90	0·1n	,,	,,	81·9
			57·2	1	60·16	0·8	,,	,,	87·1
					57·31	0·1n	,,	,,	26607·3
					56·69	0·1n	,,	,,	11·7
			56·0	1	56·11	0·4	,,	,,	15·8
			55·7	1			,,	,,	19·
					55·29	0·1n	,,	,,	21·6
			54·8	1	54·68	0·3	,,	,,	25·9
			53·4	1	53·60	0·4b	,,	,,	33·6
					53·08	0·1n	,,	,,	37·3
					52·70	0·6	,,	,,	40·0
			52·5	1			,,	,,	41·
			50·8	1	50·89	0·1n	,,	,,	52·8
50·539	50·55	1	50·5	2	50·53	0·2s	,,	,,	55·3
			48·2	1			,,	,,	72·
47·352	47·36	5	47·3	6	47·39	1·0	,,	,,	77·9
			46·4	1	46·50	0·2	,,	,,	84·1
			46·0	1			,,	,,	88·
					45·77	0·9	,,	,,	89·3
			45·6	2			,,	,,	90·
			45·2	1n			,,	,,	93·
			44·6	1	44·52	0·5b	,,	,,	98·3
					43·99	0·1n	,,	,,	26702·1
			43·6	1			,,	,,	05·
			43·4	1			,,	,,	06·
					43·02	0·8b	,,	,,	08·9
42·948		1	42·8	2			,,	,,	09·
	42·44	2	42·4	1	42·47	1·0	,,	,,	12·9
			41·8	1	41·92	0·2n	,,	,,	16·7
					40·73	0·2b	,,	,,	25·2
					39·63	0·3	,,	,,	33·1

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
					3739·69	0·1n	1·04	7·5	26737·0
3738·682	3738·66	2	3738·6	4	38·67	0·3	,,	,,	40·0
					36·19	0·1	1·03	,,	57·7
					35·60	0·1	,,	,,	62·0
34·900	34·90	3	34·8	6			,,	,,	67·0
					34·54	0·1	,,	,,	69·6
			34·4	1			,,	,,	71·
			34·0	1	34·05	0·2	,,	,,	73·1
			33·4	1			,,	,,	78·
			33·3	1	33·25	0·1	,,	,,	79·8
			32·7	1	32·76	0·1	,,	,,	82·3
			32·1	1			,,	,,	87·
31·504	31·51	2	31·3	6	31·51	0·8	,,	,,	91·3
	30·58	3	30·6		30·60	1	,,	,,	97·9
					29·75	0·2n	,,	,,	26804·0
					29·40	0·1	,,	,,	06·5
	28·16	5	28·1	2	28·19	1·2	,,	7·6	15·2
			27·4	1	27·57	0·3n	,,	,,	19·5
	27·05	4	27·0	2	27·10	1s	,,	,,	23·1
					26·25	0·3	,,	,,	29·0
25·536	25·55	2	25·6	4	25·57	0·7	,,	,,	34·0
					24·75	0·1	,,	,,	39·8
					23·61	0·3n	,,	,,	48·1
22·904		3	22·9	2			,,	,,	53·
			22·6	2	22·57	0·6	,,	,,	55·6
			22·2	1	22·12	0·1	,,	,,	78·8
21·628		1	21·7	1	21·65	0·2	,,	,,	62·3
			21·2	1			,,	,,	65·
					20·93	0·1n	,,	,,	67·4
					19·51	0·1n	,,	,,	77·7
			17·6	1			,,	,,	91·
					17·14	0·1	,,	,,	94·8
					16·34	0·1b	,,	,,	26900·6
			15·8	1			,,	,,	05·
			14·5	1	14·48	0·1n	,,	,,	14·1
					13·85	0·1	,,	,,	18·6
					12·86	0·5	,,	,,	25·8
12·630	12·66	2	12·7	4			,,	,,	27·3
			11·5	1			,,	,,	36·
					11·27	0·1n	,,	,,	37·3
					10·53	0·1n	,,	,,	42·7
			08·8	1	08·83	0·1n	,,	,,	55·1
			08·3	1n	08·18	0·2n	,,	,,	59·8
07·147	07·17	1	07·1	1	07·14	0·3	,,	,,	67·4
			06·7	1	06·70	0·2	,,	,,	70·6
					06·20	0·1n	,,	,,	74·2
			05·8	1			,,	,,	77·
			05·5	1	05·43	0·1	,,	,,	79·8
					04·57	0·1n	,,	,,	86·1
			03·7	1			,,	,,	92·
			03·5	1	03·40	0·1n	,,	,,	94·6
01·107		2	01·2	4	01·08	0·8	,,	,,	27011·4
3698·261	3698·25	2	3698·1		3698·27	0·5	,,	,,	32·1

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda+$	$\frac{1}{\lambda}-$	
			3696·6	1	3696·71	0·2	1·02	7·6	27043·5
3696·308	3696·27	1n	96·3	1n	96·23	0·3n	,,	,,	46·7
			96·0	1	95·74	0·2n	,,	,,	50·6
92·851	92·85	2	92·7	2	92·84	0·8	,,	,,	71·8
			92·3	6	92·44	1·0b	,,	,,	74·8
					90·86	0·1n	,,	,,	86·4
					90·17	0·3	,,	,,	91·4
89·476		0	89·4	6	89·45	1·0	,,	,,	96·6
88·321		1	88·2	1	88·26	0·2n	,,	,,	27105·2
	87·24	2	87·1	1	87·24	0·2	,,	,,	13·0
					86·09	0·1n	,,	,,	21·4
			84·4	4	84·51	0·5	,,	,,	33·0
			83·6	1	83·71	0·1n	,,	,,	39·0
			83·0	1	83·09	0·1n	,,	7·7	43·4
			82·4	1	82·52	0·1n	,,	,,	47·6
			81·9	1			,,	,,	52·
					81·75	0·1n	,,	,,	53·3
			81·6	1	81·10	0·1n	,,	,,	58·1
			79·5	1	79·58	0·2n	,,	,,	69·3
			78·3	1	78·51	0·2n	,,	,,	77·2
			77·1	1			,,	,,	88·
			76·7	1	76·83	0·2	,,	,,	89·6
75·160	75·15	5	75·0	8	75·16	1·0	,,	,,	27202·0
			74·0	1	74·26	0·1n	,,	,,	08·7
			73·2	1	73·30	0·1n	,,	,,	15·8
			72·0	1	72·15	0·3	,,	,,	24·3
					71·75	0·1	,,	,,	27·3
					71·03	0·2	,,	,,	32·6
					69·70	0·5	,,	,,	42·5
			68·2	1	68·36	0·1n	,,	,,	52·4
			67·8	1	67·92	0·2n	,,	,,	55·7
					66·35	0·1n	,,	,,	67·4
			65·1	1	65·12	0·2b	,,	,,	76·5
64·780	64·77	5	64·7	4	64·78	0·8	,,	,,	79·1
			64·3	1			,,	,,	83·
			63·5	1	63·54	0·3	,,	,,	88·3
			63·3	1			,,	,,	92·
61·867	61·86	5	61·7	4	61·88	0·9	,,	,,	27300·7
61·527	61·52	2	61·4	2	61·52	1·0	,,	,,	03·3
			60·6	1			,,	,,	10·2
					60·18	0·1n	,,	,,	13·4
			59·2	1			,,	,,	21·
			58·7	1			,,	,,	24·
					58·15	0·7	,,	,,	28·5
57·774		0	57·6	1	57·72	0·3	1·01	,,	31·5
					57·06	0·1n	,,	,,	36·7
					55·05	0·1n	,,	,,	51·7
			54·5	1n	54·55	0·2	,,	,,	55·4
			54·0	1n			,,	,,	60·
53·358		1	53·2	10	53·34	2·3	,,	,,	64·4
			51·5	1n			,,	,,	78·
			50·3	1	50·47	0·1	,,	,,	85·0
47·857	47·85	2n	47·8	2			,,	,,	27405·7

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		λ+	$\frac{1}{\lambda}-$	
			3647·0	1	3647·02	0·1n	1·01	7·7	27411·9
					46·21	0·1n	,,	,,	18·0
3645·468	3645·47	1	45·4	1n			,,	,,	23·6
					45·34	0·1n	,,	,,	24·6
			44·0	1n			,,	,,	35·
					43·29	0·1n	,,	,,	40·0
			43·0	1			,,	,,	42·2
41·037	41·03	3					,,	,,	57·0
			40·9	1	40·91	0·3b	,,	,,	58·0
			40·7	1			,,	,,	60·
					39·72	0·1n	,,	,,	66·9
			38·8	1	38·95	0·1	,,	7·8	72·6
			38·3	1			,,	,,	78·
			38·1	1n			,,	,,	79·
					37·58	0·1	,,	,,	83·1
					37·19	0·1n	,,	,,	86·0
36·370	36·36	8	36·2	4	36·35	1·0	,,	,,	92·2
			36·5	2			,,	,,	91·2
					35·64	0·3	,,	,,	97·8
			35·0	1	35·08	1·0	,,	,,	27501·9
					34·08	0·1	,,	,,	09·5
			33·7	1			,,	,,	12·
			31·7	1 Fe ?			,,	,,	28·
			31·5	1 Fe ?			,,	,,	29·
			30·8	1n			,,	,,	34·
29·911	29·91	3	29·9	1			,,	,,	41·1
			29·8	1	29·80	0·3b	,,	,,	41·9
29·317	29·31	2	29·3	1			,,	,,	45·6
28·843	28·84	10	28·8	4	28·82	1·2	,,	,,	49·3
			28·3	1			,,	,,	53·
	27·95	1	27·9	1			,,	,,	56·0
			26·7	1	26·88	0·2n	,,	,,	64·1
26·460	26·44	5	26·4	4	26·44	0·6	,,	,,	67·4
25·872	25·87	3	25·8	2	25·89	0·3	,,	,,	71·7
			25·4	1			,,	,,	75·
			24·7	1			,,	,,	80·
			24·3	1			,,	,,	84·
23·976	23·95	3	23·8	1	23·97	0·2n	,,	,,	86·3
			22·0	1			,,	,,	27601·
			21·7	1			,,	,,	04·
					20·54	0·1n	,,	,,	12·
			19·9	1	19·94		,,	,,	17·
19·236	19·30	2	19·3	2			,,	,,	22·1
			17·9	1			1·00	,,	33·
17·378	17·37	8	17·3	4	17·39	0·7	,,	,,	36·5
			16·4	1	16·62	0·2n	,,	,,	42·2
			15·6	1	15·68	0·1n	,,	,,	49·5
			14·5		14·59	0·1n	,,	,,	57·8
					13·95	0·1n	,,	,,	68·7
					13·28	0·1n	,,	,,	67·9
					12·59	0·2n	,,	,,	73·2
09·933	09·91	8			09·94	0·5	,,	,,	93·6
			09·0	1			,,	,,	27701·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
			3607·3″	1			1·00	7·8	27714·
3605·958	3605·99	3	05·9	10	3605·99	2·5	,,	,,	23·9
			04·9	1			,,	,,	32·
			04·5	1	04·67	0·8	,,	,,	34·0
			03·8	1	03·96	0·2	,,	,,	39·5
			02·2	1			,,	,,	53·
01·568	01·56	4	01·5	1	01·59	0·3	,,	,,	57·9
			00·5	2	00·54	0·1	,,	,,	65·8
			3599·8	1	3599·94	0·5	,,	,,	70·6
98·936	98·91	3			98·92	3·	,,	,,	78·3
				1	98·29	0·1n	,,	,,	83·1
					97·9	0·1n	,,	,,	86·1
					97·30	0·2	,,	,,	90·8
96·356		0	96·4	1	96·37	1·1	,,	,,	98·1
			95·6				,,	,,	27804·
			95·0	1			,,	7·9	08·
94·557	94·56	5	94·5	4	94·60	0·8	,,	,,	11·8
94·308	94·30	3	94·3	1			,,	,,	13·9
	93·16	3 Ru ?	93·1	2	93·21	1·1	,,	,,	22·6
			92·2	1			,,	,,	30·
			91·9	1			,,	,,	32·
					91·55	0·1n	,,	,,	35·2
			91·3	1			,,	,,	37·
					89·90	1·1n	,,	,,	48·
	89·34	3 Pt?	89·3	2	89·43	1·1	,,	,,	52·
			88·9	1n			,,	,,	56·
			88·3″	1n			,,	,,	60·
			87·3	1	87·41	0·3b	,,	,,	67·4
			87·1	1			,,	,,	70·
			86·3	1	86·39	0·1n	,,	,,	75·3
			85·8	1			,,	,,	80·
			85·3	1n	85·50	0·1n	,,	,,	83·2
			84·6	1	84·72	0·2n	,,	,,	88·3
			83·5	2	83·62	0·2n	,,	,,	96·8
	83·24	10 Rh ?	83·2	2	83·30	0·1	,,	,,	99·6
			81·0	1	80·97	0·1n	,,	,,	27917·5
			78·2	1			,,	,,	39·
			77·7	1			0·99	,,	43·
			77·3	1	77·24	0·2n	,,	,,	46·6
			76·9	1			,,	,,	49·
			76·3	1			,,	,,	54·
			75·9	1			,,	,,	57·
			75·6	1			,,	,,	59·
			75·2	1			,,	,,	62·
			74·9	1n			,,	,,	65·
			74·6	1	74·75	0·1n	,,	,,	66·1
3573·888	73·89	10	73·8	8	73·87	1·45	,,	,,	72·9
			73·1	1			,,	,,	79·
			72·9	1			,,	,,	80·
			72·5	1			,,	,,	84·
			72·1	1			,,	,,	87·
			71·9	1			,,	,,	88·
			70·7	1	70·74	0·4	,,	,,	97·5

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		λ+	$\frac{1}{\lambda}$−	
			3570·0	1			0·99	7·9	28003·
					3569·95	0·1	,,	,,	03·7
			69·5	1n			,,	,,	07·
3568·156			68·1	2	68·17	2·	,,	,,	17·7
					67·40	0·1n	,,	,,	23·7
					66·59	0·5	,,	,,	30·1
			64·8	1	64·96	0·2n	,,	,,	42·9
			63·0	1	63·02	0·1n	,,	,,	58·2
					62·78	0·1	,,	,,	60·1
			61·5	1	61·03	0·5	,,	,,	73·9
			60·5″	1			,,	,,	78·
			60·0	1			,,	,,	82·
					59·95	0·2	,,	,,	82·4
			59·8	1			,,	,,	84·
59·160	3559·15	8			59·17	1·	,,	,,	88·6
			58·2″	1			,,	,,	96·
57·325	57·35	5	57·3	4	57·36	1·	,,	,,	28102·9
			56·6	1			,,	,,	09·
			55·9	1	55·90	0·1n	,,	,,	14·4
			55·8	1			,,	,,	15·
			54·7	1			,,	,,	24·
			53·9	1	54·05	0·1	,,	,,	29·
			53·7	1			,,	,,	32·
	53·26	2 Pd?					,,	,,	35·3
			52·7	1			,,	,,	40·
52·223	52·27	2	52·2	2	52·31	0·1	,,	,,	43·1
			51·4	1	51·54	0·1	,,	8·0	48·0
			50·7	1			,,	,,	56·
			50·3	1			,,	,,	59·
					49·74	0·1n	,,	,,	63·1
			48·7	2	48·77	0·1n	,,	,,	70·8
			47·2	1n			,,	,,	83·
	46·60	1n	46·5	1			,,	,,	88·
			46·2	1			,,	,,	91·
			45·8	1			,,	,,	94·
			45·2	1			,,	,,	99·
			44·7	1			,,	,,	28203·
			44·2	1	44·15	0·1n	,,	,,	07·5
					43·46	0·1n	,,	,,	13·
			42·7	1	42·88	0·1	,,	,,	17·6
			42·1	1			,,	,,	24·
					41·81	0·1n	,,	,,	26·1
			41·6	1			,,	,,	28·
			40·8	1			,,	,,	34·
			39·5	1	39·47	0·2	,,	,,	44·8
			38·7	1			,,	,,	51·
					38·10	0·1n	,,	,,	55·8
			37·6	1			0·98	,,	60·
			37·2	1			,,	,,	63·
			36·9	1			,,	,,	65·
			36·7	1			,,	,,	67·
			36·4	1			,,	,,	69·
			35·9	1	35·99	0·4	,,	,,	72·6
			34·5	1			,,	,,	85·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3534·3	1			0·98	8·0	28286·
					3532·99	0·1n	,,	,,	96·6
			32·4	1	32·41	0·1	,,	,,	28301·3
			31·7	1			,,	,,	07·
			31·5	1	31·47	0·1n	,,	,,	08·8
			30·8	1	30·88	0·1n	,,	,,	13·6
			28·7	1	28·75	0·2	,,	,,	30·6
					28·15	0·3	,,	,,	35·5
			26·8	1	26·87	0·1n	,,	,,	45·8
			24·0	1			,,	,,	69·
			23·4	1			,,	,,	74·
3522·191	3522·21	6	22·4	4	22·17	0·6	,,	,,	83·3
			20·3	1n	20·19	0·1n	,,	,,	99·6
			19·7	1			,,	,,	28404·
					18·85	0·1n	,,	,,	10·4
			18·6	1			,,	,,	12·
					17·03	0·1n	,,	,,	25·1
16·110	16·11	6	16·0	4	16·07	0·3	,,	,,	32·6
					14·60	0·1	,,	,,	44·7
13·807	13·82	10	13·7	6	13·80	1·2	,,	,,	51·1
12·356	12·36	3	12·3	2	12·35	0·1	,,	,,	62·9
12·054	12·04	3	11·9	1	12·04	0·1	,,	,,	65·4
10·793	10·80	3	10·7	1	10·79	0·2	,,	,,	75·6
			10·3	1			,,	8·1	82·
			09·4	1	09·37	0·5	,,	,,	87·
			09·0	1			,,	,,	90·
08·731	08·71	1					,,	,,	92·5
			08·4	1			,,	,,	95·
					07·64	0·2	,,	,,	28501·1
			06·2	1	06·13	0·1	,,	,,	13·4
			05·2	1n			,,	,,	21·
					04·78	0·1n	,,	,,	24·3
			04·3	1			,,	,,	28·
03·088	03·09	2	03·0	1			,,	,,	38·1
					02·69	0·3	,,	,,	41·4
			01·6	1n			,,	,,	50·
			00·8	1	00·85	0·1n	,,	,,	56·4
			00·5	1n			,,	,,	69·
3499·271		1	3499·0		3499·08		,,	,,	70·8
			98·3	1			0·97	,,	77·
			97·8	1			,,	,,	81·
					97·14	0·2	,,	,,	86·7
96·580	3496·59	1	96·5	1n			,,	,,	91·2
			96·0	1n			,,	,,	96·
					95·93	0·1n	,,	,,	96·5
			95·5	1n			,,	,,	28600·
94·787	94·79	3	94·8	2	94·81	0·1	,,	,,	05·9
			93·7	1			,,	,,	15·
			93·2	1			,,	,,	19·
92·217	92·21	1	92·3	1			,,	,,	27·0
			92·0	1			,,	,,	29·
			91·3	1			,,	,,	35·
			89·2	1			,,	,,	38.
			90·9	1			,,	,,	41·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
			3490·5	1			0·97	8·1	28652·
3488·727	3488·73	3	88·7	1			,,	,,	55·7
			88·2	1n			,,	,,	60·
			87·6	1			,,	,,	65·
			86·2	1			,,	,,	77·
85·660	85·68	3	85·6	1			,,	,,	80·8
84·649	84·66	4	84·6	1	3484·65	0·1	,,	,,	89·2
84·256	84·26	3	84·3	1	84·21	0·1	,,	,,	92·5
	83·63	1					,,	,,	97·6
			83·2	1			,,	,,	28701·1
82·760	82·78	4			82·73	0·1	,,	,,	04·7
			82·5	1			,,	,,	07·
			81·5	1			,,	,,	15·
					81·35	0·1n	,,	,,	16·
81·254	81·26	3					,,	,,	17·2
			80·7	1n			,,	,,	22·
			79·9	1			,,	,,	28·
			79·4	1	79·50	0·1	,,	,,	31·7
77·930		1	78·0	2	77·90	0·1n	,,	,,	44·8
76·611	76·60	3	76·7	2	76·62	0·1n	,,	,,	55·6
			76·3	1			,,	,,	58·
76·182	76·17	1					,,	,,	59·1
			75·8	1			,,	,,	62·
					74·96	0·1n	,,	,,	69·2
			74·5	1			,,	,,	73·
					74·36	0·1n	,,	,,	74·2
			73·6	1			,,	,,	80·
			73·3	1			,,	,,	83·
	72·98	1	72·7	1			,,	,,	85·6
			72·0	1			,,	,,	94·
					70·85	0·1	,,	8·2	28803·2
			70·2	1			,,	,,	09·
	69·79	2					,,	,,	11·9
68·749	68·75	2					,,	,,	21·5
	68·02	1	68·1	1			,,	,,	26·7
			67·1	1			,,	,,	34·
			66·2	1			,,	,,	42·
65·390	65·39	3	65·5	2	65·38	0·1	,,	,,	48·6
					62·23	0·1	,,	,,	74·9
			61·8	1			,,	,,	79·
			61·3	1			,,	,,	83·
			60·0	1n			,,	,,	94·
			58·8	2	58·85	0·1	0·96	,,	28903·1
	58·10	2					,,	,,	09·4
			57·4	1n			,,	,,	15·
	57·25	1					,,	,,	16·5
55·949	55·95	1	56·0	1			,,	,,	27·4
			55·1	1			,,	,,	35·
			52·1	1			,,	,,	60·
			51·7	1			,,	,,	63·
50·916	50·93	1	51·0	1			,,	,,	69·6
			50·3	1			,,	,,	75·
49·133	49·13	10	49·2	4	49·10	0·3	,,	,,	84·7
48·621	48·61	1	48·8	1			,,	,,	88·9

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum				Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		Lohse		$\lambda +$	$\frac{1}{\lambda} -$	
	3447·90	1	3448·0	1			0·96	8·2	28995·
3446·793	46·79	2	46·8	1			,,	,,	29004·3
46·476	46·49	2	46·4	1	3446·48	0·1	,,	,,	06·9
45·682		0	45·5	1n			,,	,,	13·6
			44·2	1			,,	,,	26·
					40·71	0·1n	,,	,,	55·6
			39·0	1n			,,	,,	70·
38·244	38·21	2	38·2	1n			,,	,,	76·6
37·670	37·65	4	37·6	4	37·69	0·3	,,	,,	81·3
37·189	37·20	10	37·2	6	37·19	0·3	,,	,,	85·3
					36·88	0·1	,,	,,	88·
35·554		0					,,	,,	99·2
35·200		0					,,	,,	29102·2
34·915		2			35·07	0·2n	,,	,,	04·6
33·475	33·46	2	33·4	1			,,	,,	16·9
32·930	32·92	1					,,	8·3	21·4
	32·20	1	32·3	1			,,	,,	27·5
			31·6	1			,,	,,	33·
31·476	31·45	1					,,	,,	33·8
30·941	30·94	1	31·1	1			,,	,,	38·2
30·197	30·20	1	30·0	1			,,	,,	44·5
29·748		0					,,	,,	48·4
29·026	29·01	2	29·1	1			,,	,,	54·6
			28·6	1			,,	,,	58·
	28·47	3			28·47	0·1	,,	,,	59·2
			28·3	1			,,	,,	61·
			27·7	1			,,	,,	66·
			27·3	1			,,	,,	69·
			26·8	1n			,,	,,	74·
			26·0	1n			,,	,,	80·
25·526	25·50	1	25·5	1			,,	,,	84·4
24·854	24·85	3	24·9	1			,,	,,	90·0
			23·9	1			,,	,,	98·
21·923	21·93	2	22·0	1			,,	,,	29215·0
			21·5	1			,,	,,	19·
20·895		0					,,	,,	23·8
20·646	20·64	3	20·8	1			,,	,,	26·0
20·111		0	20·2	1			,,	,,	30·5
19·592	19·57	3	19·6	2			,,	,,	35·0
18·533	18·54	1					,,	,,	44·0
			17·5	1	17·46	0·1n	0·95	,,	53·2
			16·3	1			,,	,,	63·
15·906	15·87	2	15·8	1			,,	,,	66·7
15·408	15·39	3	15·4	1n			,,	,,	70·8
			14·9	1			,,	,,	75·
			13·4	1			,,	,,	88·
12·762	12·75	2	12·6	1			,,	,,	93·5
11·730	11·72	2	11·7	1			,,	,,	29302·3
			10·3	1			,,	,,	15·
10·180	10·19	1	10·2	1			,,	,,	15·6
09·931	09·91	1	10·	1			,,	,,	17·9
	09·40	1n	09·5	1			,,	,,	22·4
			08·2	1	08·32	0·1n	,,	,,	31·7
			05·5	1			,,	,,	56·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Lohse	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda+$	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
			3403·6	1n			0·95	8·3	29372·
3402·962	3402·95	2	03·0	1			,,	,,	77·8
02·182	02·17	2					,,	,,	84·6
01·927	01·92	3	01·9	1			,,	,,	96·8
			3398·3	1n			,,	,,	29418·
			97·5	1			,,	,,	25·
			97·1	1			,,	,,	29·
			96·3	1			,,	,,	36·
			96·0	1			,,	8·4	38·
3395·129	3395·14	3	95·2	2			,,	,,	45·5
			93·6	1			,,	,,	59·
			92·7	2			,,	,,	67·
			91·5	1			,,	,,	77·
91·032	91·05	1	91·1	1			,,	,,	81·0
89·473		1					,,	,,	94·7
			88·9	1			,,	,,	29500·
88·158	88·15	1	88·1	1			,,	,,	06·2
88·023	88·05	1					,,	,,	07·1
			87·8	1			,,	,,	09·
86·678		0					,,	,,	19·0
86·330	86·34	3	86·4	1			,,	,,	22·1
	85·91	1					,,	,,	25·7
85·752	85·76	2	85·7	1			,,	,,	27·1
85·272	85·27	2	85·3	1			,,	,,	31·3
			85·0	1			,,	,,	34·
83·917	83·91	1	83·9	1n			,,	,,	43·2
83·474		0					,,	,,	47·0
			82·2	1			,,	,,	58·
			81·6	1			,,	,,	63·
			81·3	1			,,	,,	66·
81·151	81·18	3					,,	,,	67·2
79·993	80·01	1	80·0	1			,,	,,	77·4
			79·5	1			,,	,,	82·
78·550		0n	78·5	1			,,	,,	90·1
78·219		0n	78·1	1			,,	,,	93·9
77·288		0n					0·94	,,	29601·2
76·146	76·15	1	76·2	1			,,	,,	11·2
			75·5	1n			,,	,,	16·8
74·942		0					,,	,,	21·7
74·597	74·61	1	74·6	1			,,	,,	24·7
	74·16	1	74·1″	1			,,	,,	28·6
72·958	72·96	1	72·7	2			,,	,,	39·2
71·594	71·60	4	71·5	2			,,	,,	51·1
70·785	70·78	3	70·7	1			,,	,,	58·3
	69·14	1					,,	,,	72·8
68·640	68·64	8	68·0	1	3468·57	0·1n	,,	,,	77·2
67·210	67·21	2					,,	,,	89·8
67·063	67·09	2	67·0	1			,,	,,	91·0
			66·6	1			,,	,,	96·
			66·3	1			,,	,,	98·
65·678	65·69	1	65·6	1			,,	,,	29703·2
65·273		0					,,	,,	06·9
					64·75	0·1n	,,	,,	11·5

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3364·380	3364·40	2	3364·4	1	0·94	8·4	29714·7
			61·8	1	,,	,,	38·
			61·6	1	,,	,,	39·
			61·2	1	,,	,,	43·
60·950		7			,,	8·5	45·0
			60·2	1n	,,	,,	52·
60·038	60·00	1n			,,	,,	53·1
	59·90	3	59·9	1n	,,	,,	54·3
	59·63	2	59·7	1	,,	,,	56·7
59·262		0			,,	,,	59·9
			58·3	1	,,	,,	68·
			58·2	1	,,	,,	69·
56·697		0			,,	,,	82·7
56·342		0			,,	,,	85·8
55·942	55·95	2	55·9	1	,,	,,	89·3
55·739		0			,,	,,	91·2
			55·5	1	,,	,,	93·
			55·3	1	,,	,,	95·
53·696	53·70	1	53·7	1	,,	,,	29809·3
52·987	53·00	2	52·9	1	,,	,,	15·6
			52·3	1n	,,	,,	22·
			51·5	1n	,,	,,	29·
			50·2	1	,,	,,	40·
			50·0	2	,,	,,	42·
			48·1	1	,,	,,	59·
48·015		1	48·0	1	,,	,,	60·0
47·695	47·72	2	47·6	1	,,	,,	62·7
46·609	46·61	1	46·6	1n	,,	,,	72·5
			45·5	1	,,	,,	82·
			44·7	1n	,,	,,	90·
44·360	44·36	2	44·4	1	,,	,,	92·6
43·745	43·55	1n			,,	,,	98·9
43·182		0	43·1	1	,,	,,	29903·1
42·930		0			,,	,,	05·5
			42·5	1	,,	,,	09·
			42·0	1n	,,	,,	14·
			41·0	1	,,	,,	23·
40·485	40·50	3	40·6	1	,,	,,	27·2
			40·3	1	,,	,,	29·
	39·70	1n	39·6	1	,,	,,	34·3
39·532	39·56	4			,,	,,	35·6
39·028		0			,,	,,	40·3
38·535	38·56	5	38·5	2	0·93	,,	44·6
37·985		1	37·9	2	,,	,,	49·7
37·637		0	37·5	1	,,	,,	52·8
36·195	36·21	1	36·2	1	,,	,,	65·7
			35·7	1	,,	,,	70·
35·185		0			,,	,,	74·8
			34·9	1	,,	,,	77·
34·318	34·35	6	34·3	4	,,	,,	82·5
33·600		0			,,	,,	89·1
30·968		0	27·9	1	,,	,,	30012·6
27·688		0			,,	,,	42·4
27·039	27·04	2			,,	,,	48·3

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ +	1/λ −	
3326·687		0			0·93	8·5	30051·4
26·245	3326·25	1	3326·3	1	,,	,,	55·4
26·056		0			,,	,,	57·1
	25·58	1	25·5	1b	,,	,,	61·4
			23·9	1	,,	8·6	77·
23·011	23·03	4	23·1	2	,,	,,	84·5
			22·9	4	,,	,,	86·
22·750	22·77	5	22·7	4	,,	,,	86·9
21·901		0			,,	,,	94·6
			20·7	1n	,,	,,	30106·
20·504		1			,,	,,	07·3
19·680		0			,,	,,	14·8
19·231	19·25	1	19·2	1n	,,	,,	18·8
18·812		0			,,	,,	22·6
18·596	18·60	1	18·6	1n	,,	,,	24·6
17·664		0			,,	,,	33·1
17·457	17·45	1	17·5	1	,,	,,	35·0
16·771	16·80	2	16·7	1	,,	,,	41·1
16·534		0n			,,	,,	43·4
16·129		0			,,	,,	47·1
13·472					,,	,,	71·2
12·268	12·31	4	12·3	1	,,	,,	82·0
11·365		0	11·3	1n	,,	,,	90·4
11·161	11·16	1			,,	,,	92·3
10·674	10·69	5	10·7	2	,,	,,	96·6
10·032		0			,,	,,	30202·6
09·535	09·55	1	09·6	1	,,	,,	07·0
08·939		0			,,	,,	12·6
08·581	08·57	1n			,,	,,	15·9
07·774	07·78	1	07·8	1n	,,	,,	23·2
			06·6	1	,,	,,	34·
05·980	05·99	1	06·0″	1n	,,	,,	39·6
05·787	05·80	1			,,	,,	41·3
			05·2	1	,,	,,	47·
05·057	05·07	2			,,	,,	48·0
04·460		0			,,	,,	53·5
03·771	03·78	2	03·7	1	,,	,,	59·8
03·236	03·24	2			,,	,,	64·7
			02·7	1n	,,	,,	70·
01·900		1	02·0	1	,,	,,	77·0
01·735		0			,,	,,	78·5
01·502		0			,,	,,	80·6
00·732		0			,,	,,	87·6
			3299·3	1n	0·92	,,	30301·
			99·0	1	,,	,,	04·
			98·3	1	,,	,,	10·
3297·655	3297·65	2	97·6	1	,,	,,	16·0
			97·4	1n	,,	,,	18·
95·220	95·24	2	95·3	1	,,	,,	38·3
			94·7	1	,,	,,	43·
94·251		0	94·3	1	,,	,,	47·3
94·150		0			,,	,,	48·2
			93·6	1	,,	,,	53·
			93·3	1	,,	,,	56·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			3292·6	1	0·92	8·6	30363·
			92·2	1	,,	,,	66·
			91·6	1	,,	,,	72·
3291·187		0	91·4	1	,,	,,	75·6
91·010		0			,,	,,	77·2
90·640		0	90·2	1	,,	,,	80·6
			89·2	1	,,	8·7	94·
			88·7	1	,,	,,	99·
			88·4	1	,,	,,	30401·
87·726	3287·72	5	87·7	1	,,	,,	07·5
87·198	87·20	4	87·2	1	,,	,,	12·3
85·721		0	85·7	1n	,,	,,	26·0
84·695	84·69	2	84·6	2	,,	,,	35·5
84·456		1			,,	,,	37·7
			84·0	1	,,	,,	42·
82·458	82·46	2	82·5	1	,,	,,	56·3
			82·3	1	,,	,,	58·
82·024		0			,,	,,	61·3
	81·85	1	81·8	1	,,	,,	67·9
			81·2	1n	,,	,,	68·
80·705		1	80·6	1	,,	,,	72·5
80·011		0			,,	,,	79·0
			79·6	1	,,	,,	83·
			79·1	1	,,	,,	87·
	78·41	1	78·2	1	,,	,,	93·9
			77·9	1	,,	,,	99·
77·422	77·41	5	77·4	1	,,	,,	30503·1
76·291	76·28	1	76·3	1	,,	,,	13·7
75·735	75·74	2			,,	,,	18·8
75·452	75·45	1	75·6	1	,,	,,	21·4
75·167	75·15	1	75·0	1	,,	,,	24·0
74·686	74·68	2			,,	,,	28·6
			74·2	1	,,	,,	33·
72·772		0	72·7	1	,,	,,	46·4
			72·5	1	,,	,,	49·
71·936	71·94	3	71·8	1	,,	,,	54·2
71·372	71·38	4	71·4	1	,,	,,	59·5
69·835		0			,,	,,	73·9
			69·5	1n	,,	,,	77·
68·663		0	68·7	1	,,	,,	84·9
			68·5	1	,,	,,	86·
67·236	67·22	1	67·2	1n	,,	,,	98·3
66·580	66·59	8	66·5	2	,,	,,	30604·3
65·399		0			,,	,,	15·4
			64·6	1	,,	,,	23·
			64·3	1	,,	,,	26·
63·436	63·44	1n			,,	,,	33·8
63·062	63·09	1	63·1	1	,,	,,	37·2
62·852	62·85	1			,,	,,	39·3
			62·6	1	,,	,,	42·
62·147	62·15	5	62·1	2	,,	,,	45·9
			61·4	1	,,	,,	54·
			61·0	1n	,,	,,	57·
			59·7	1n	0·91	,,	69·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	1/λ −	
			3259·0″	1	0·91	8·7	30676·
3257·916					,,	,,	85·8
	3256·92	2	56·9	1n	,,	,,	95·1
56·346		1			,,	,,	30700·6
56·194		2			,,	,,	02·0
			55·9	1	,,	,,	05·
	55·20	2	55·1	1	,,	,,	11·4
54·542	54·54	4	54·4	4	,,	,,	17·6
53·497		1	53·4	2	,,	,,	27·4
			52·0″	1n	,,	8·8	42·
49·866	49·87	3	49·8	1	,,	,,	61·7
49·638	49·63	2	49·6	1	,,	,,	63·9
47·417		1			,,	,,	84·9
46·951		0	46·9	1	,,	,,	89·3
46·431		2	46·3	1	,,	,,	94·2
45·510		0	45·4	1n	,,	,,	30803·0
45·022	45·02	1	45·0	1	,,	,,	07·6
44·887		0			,,	,,	08·9
43·568		0	43·8	1	,,	,,	21·4
42·734	42·78	1			,,	,,	29·1
42·462	42·47	1	42·4	1	,,	,,	32·9
42·132		1			,,	,,	35·1
41·640	41·65	6	41·6	4	,,	,,	39·7
41·395		0			,,	,,	42·1
40·688	40·69	1	40·7	1	,,	,,	48·8
40·351	40·35	3	40·4	1	,,	,,	52·2
			39·5	1b	,,	,,	60·
38·675		0	38·5	1	,,	,,	67·1
38·414		1			,,	,,	70·5
38·003		0	37·9	1	,,	,,	74·4
			37·4	1n	,,	,,	80·
37·115		0	37·0	1	,,	,,	82·9
			36·1	1	,,	,,	93·
			35·7	1	,,	,,	96·
35·537		0			,,	,,	98·0
35·370		0	35·3	1	,,	,,	99·6
			34·5	1	,,	,,	30908·
			33·0	1	,,	,,	22·
32·618		0	32·8	1	,,	,,	25·9
32·342		1			,,	,,	28·5
32·145	32·14	4n	32·0	4	,,	,,	30·4
			31·7	1n	,,	,,	35·
			31·2	1	,,	,,	39·
30·903	30·90	4			,,	,,	42·3
			30·7	2	,,	,,	44·
29·412	29·40	5	29·3	4	,,	,,	56·6
28·672		0	28·6	2	,,	,,	63·7
27·675		0	27·8	1	,,	,,	73·2
			27·0	1	,,	,,	80·
26·840	26·83	2	26·7	1	,,	,,	81·3
			25·8	1	,,	,,	91·
			25·5	1	,,	,,	94·
24·637		0	24·5	1	,,	,,	31002·4
24·016	24·06″	1n			,,	,,	08·2

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3223·645	3223·65	1	3223·6	1	0·91	8·8	31012·0
23·138		0	23·0	1	,,	,,	16·9
22·854		0			,,	,,	19·6
22·600		1	22·5	4	,,	,,	22·0
			22·4	2	,,	,,	24·
21·415	21·40	4	21·3	2	,,	,,	33·5
20·924	20·91	10	20·7	6	0·90	,,	38·2
	19·66	6	19·6	2	,,	,,	50·4
18·593	18·60	4	18·6	1	,,	,,	60·6
17·700	17·70	1			,,	,,	69·3
17·301		0	17·3	1n	,,	,,	73·2
16·905		1			,,	,,	77·0
16·431		0	16·5	1	,,	8·9	81·5
			15·2	1	,,	,,	93·
			14·3	1	,,	,,	31102·
			14·0	1	,,	,,	05·
13·681	13·68	3	13·6	1	,,	,,	08·1
			13·2	1	,,	,,	13·
12·629		0			,,	,,	18·2
12·350	12·37	4	12·1	8	,,	,,	20·8
12·240	12·22	4			,,	,,	22·1
			11·5	1	,,	,,	29·
			11·4	1	,,	,,	30·
10·131		2			,,	,,	42·5
			09·9	1	,,	,,	45·
			09·6	1	,,	,,	48·
09·050		0	09·1	1	,,	,,	53·0
08·287	08·27	2	08·1	1	,,	,,	60·5
	07·22	1	07·0	1	,,	,,	70·8
			06·3	1	,,	,,	80·
05·837		0	05·7	1	,,	,,	84·2
05·227	05·22	3	05·1	1	,,	,,	90·2
04·587		2	04·5	1	,,	,,	96·4
04·230		0			,,	,,	99·8
			03·2	1	,,	,,	31210·
			02·7	1	,,	,,	15·
02·250		0			,,	,,	19·1
02·023		0			,,	,,	21·3
			01·8		,,	,,	24·
01·027	01·02	2	01·0	1	,,	,,	31·1
00·166	00·16	1n	00·1	1	,,	,,	39·5
3199·058	3199·06	5	3199·0	2	,,	,,	50·3
98·226	98·23	1	98·1	1	,,	,,	58 4
			97·5	1	,,	,,	65·
95·882		0	95·7	1	,,	,,	81·4
			94·2	1	,,	,,	98·
93·345		2			,,	,,	31306·2
93·240		1	93·2	1	,,	,,	07·3
			90·6	1	,,	,,	33·
			90·2	1n	,,	,,	37·
89·486	89·47	1	89·4	1	,,	,,	44·2
88·702		1	88·7	1	,,	,,	51·8
88·487		0			,,	,,	53·9
87·267		0	87·3	1	,,	,,	65·9

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
3186·667		1	3186·8	1	0·90	8·9	31371·8
86·184		0			,,	,,	76·6
86·030		0			,,	,,	78·1
			85·7	1	,,	,,	81·
			85·4	1	,,	,,	84·
			84·8	1	,,	,,	90·
			83·7	1n	,,	,,	31401·
82·924		1			,,	,,	08·7
			82·8	1n	,,	,,	10·
82·514		0			,,	,,	12·8
			82·0	1n	,,	,,	18·
			81·4	1	0·89	,,	24·
80·487	3180·48	4	80·4	1	,,	9·0	32·8
79·328	79·32	3	79·2	1n	,,	,,	44·2
79·811	78·80	1	78·7	1	,,	,,	49·4
			78·4	1	,,	,,	53·
77·712	77·70	4	77·6	1	,,	,,	60·2
77·325		0	77·2	1	,,	,,	64·0
			76·7	1	,,	,,	70·
76·106		0	76·0	1	,,	,,	76·1
			75·3	1n	,,	,,	84·
			74·8	1	,,	,,	89·
73·466		3	73·3	1	,,	,,	31502·3
73·222		0			,,	,,	04·7
72·915	72·91	3	72·9	1	,,	,,	07·8
71·812	71·80	2	71·7	1	,,	,,	18·8
			71·5	1	,,	,,	22·
			71·3	1	,,	,,	24·
			70·0	1	,,	,,	37·
69·010	69·01	6	69·2	4	,,	,,	46·6
68·673		0			,,	,,	49·9
68·404		1	68·4	2	,,	,,	52·6
68·297	68·30	4			,,	,,	53·7
67·792		0			,,	,,	58·7
67·328	67·30	3	67·3	1	,,	,,	63·5
66·886	66·85	1	66·8	1	,,	,,	67·9
			66·3	1n	,,	,,	74
65·833		1			,,	,,	78·3
65·323		1	65·3	1	,,	,,	83·4
64·376		0	64·1	2	,,	,,	92·8
63·972		1			,,	,,	96·8
62·953		0	63·0	1	,,	,,	31607·0
62·871		0			,,	,,	07·8
62·445		0	62·5	1	,,	,,	12·1
61·948	61·95	2	61·9	1	,,	,,	17·1
61·477	61·49	2	61·4	1	,,	,,	21·7
59·992		1	60·1	1	,,	,,	36·6
59·644	59·64	2	59·6	1	,,	,,	40·2
59·280	59·29	4	59·2	1	,,	,,	43·7
			58·6	1	,,	,,	50·6
57·836		0			,,	,,	58·5
57·614	57·60	2	57·6	1	,,	,,	60·6
			57·1	1	,,	,,	66·
56·274	56·28	2	56·3	1	,,	,,	73·9

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	1/λ −	
			3155·2	1n	0·89	9·0	31685·
3154·874	3154·85	3	54·8	2	,,	,,	88·1
54·679	54·66	3	54·7	1	,,	,,	90·0
			52·7	1	,,	,,	31710·
51·748	51·75	1n	51·7	1n	,,	,,	19·4
50·727	50·76	4	50·7	1	,,	,,	29·6
50·128		0			,,	,,	35·7
			49·6	1	,,	,,	41·
			49·0	1	,,	,,	47·
48·346		0			,,	,,	53·7
			48·1	1	,,	,,	56·
47·860	47·85	1	47·9	1	,,	,,	58·7
			46·9	1	,,	9·1	68·
			46·6	1	,,	,,	71·
			45·7	1n	,,	,,	80·
	45·17	3	45·2	2	,,	,,	85·7
			44·5	1	,,	,,	93·
			44·4	1	,,	,,	94·
			44·0	1	,,	,,	98·
43·668		0			,,	,,	31800·9
42·994		0			,,	,,	07·7
42·371		1			,,	,,	14·0
					,,	,,	18·3
41·946		1	41·2	2	0·88	,,	26·
	40·52	3	40·4	1	,,	,,	32·8
39·704	39·70	1			,,	,,	41·1
			38·6	1n	,,	,,	52·
			37·8	6	,,	,,	60·
36·418	36·56	1n			,,	,,	73·7
			35·5	1n	,,	,,	84·
35·358		0			,,	,,	85·2
			35·0	1n	,,	,,	89·
			34·2	1	,,	,,	97·
	33·89	1			,,	,,	31900·1
33·432	33·45	8 nr	33·4	6	,,	,,	04·7
33·210	33·23	3			,,	,,	07·0
			32·7	1	,,	,,	12·
			32·3	1	,,	,,	16·
			29·9	1	,,	,,	41·
			29·7	1	,,	,,	43·
			29·3	1	,,	,,	47·
28·510	28·51	3	28·6	2	,,	,,	55·0
			26·9	1	,,	,,	72·
			25·0	1	,,	,,	91·
24·203	24·20	1	24·3	1	,,	,,	99·1
24·024		0			,,	,,	32000·9
23·334		2			,,	,,	08·0
	22·82	1	22·62		,,	,,	13·2
22·509	22·50	3			,,	,,	16·5
21·894	21·91	4	22·1	4	,,	,,	22·7
20·885	20·90	5	20·9	2	,,	,,	33·0
			20·5	1	,,	,,	37·
			19·8	1	,,	,,	44·
19·422		0			,,	,,	48·1

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
3118·967		1	3118·9	2	0·88	9·1	32052·8
17·968		0			,,	,,	63·1
17·645	3117·64	1			,,	,,	66·4
			17·4	2	,,	,,	69·
			16·3	1	,,	,,	80·
14·669	14·69	3	14·6	1	,,	,,	96·9
14·170	14·16	3 Pd ?	14·2	1	,,	9·2	32101·1
13·908		1			,,	,,	04·9
13·229		1			,,	,,	12·1
12·475	12·48	2	12·5	1	,,	,,	19·5
			12·2	1	,,	,,	23·
			10·4	1	,,	,,	41·
			10·0	1	,,	,,	45·
	09·49	1	09·5	1	,,	,,	50·4
08·670	08·67	1	08·7	1	,,	,,	58·9
			08·2	1	,,	,,	64·
			07·7	1	,,	,,	69·
			07·3	1	,,	,,	73·
			06·8	1	,,	,,	78·
06·072		0	06·2	1	,,	,,	85·8
			05·3	1	,,	,,	94·
04·301		0	04·3	1	,,	,,	32204·2
03·875	03·88	1	03·9	1	,,	,,	08·6
			02·8	1n	,,	,,	20·
01·288	01·29	2	01·3	1	0·87	,,	35·5
00·586	00·50	8	00·5	6	,,	,,	43·2
			3099·9	1	,,	,,	50·
			99·6	1	,,	,,	53·
			99·2	1	,,	,,	57·
3099·055	3099·05	1n			,,	,,	58·7
			98·7	1	,,	,,	62·
98·555		0			,,	,,	63·9
			98·4	1	,,	,,	66·
97·931	97·94	2	97·9	1	,,	,,	70·4
			95·4	1	,,	,,	97·
	94·49	1	94·6	1	,,	,,	32306·3
94·326		1	94·3	1	,,	,,	08·0
94·144	94·14	2	94·1	1n	,,	,,	09·9
			93·5	1	,,	,,	17·
			93·1	1	,,	,,	21·
			92·8	1	,,	,,	24·
			92·5	1	,,	,,	27·
			91·6	1n	,,	,,	37·
91·254		0			,,	,,	40·1
90·871		0			,,	,,	44·1
90·277	90·29	2	90·1	1	,,	,,	50·3
89·660		0			,,	,,	56·8
88·163	88·15	5	88·2	6	,,	,,	62·6
			87·7	1	,,	,,	77·
			87·3	1	,,	,,	82·
86·564	86·58	4	86·5	2	,,	,,	89·2
			86·0	1n	,,	,,	95·
			85·3	1	,,	,,	32403·
85·088		1			,,	,,	04·8

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3083·343	3083·37	4	3083·3	4	0·87	9·3	32422·9
83·085		1	83·0	4	,,	,,	25·7
82·823		0			,,	,,	28·4
		0	82·2	1n	,,	,,	35·
81·709		1	81·6	1n	,,	,,	40·2
			81·0	1n	,,	,,	48·
			80·2	1	,,	,,	56·
79·892		0	79·9	1	,,	,,	59·4
78·793		2			,,	,,	71·0
	78·70	1			,,	,,	71·9
77·996	78·00	1			,,	,,	79·4
	77·75	2	77·7	1	,,	,,	82·0
76·800	76·80	3	76·8	2	,,	,,	92·0
75·577		0	75·6	2	,,	,,	32504·9
			75·0	1	,,	,,	11·
74·864	74·87	2			,,	,,	12·4
			74·5	1	,,	,,	16·
73·800		0			,,	,,	23·7
73·390	73·42	2	73·5	2	,,	,,	27·9
72·904		0	72·7	1	,,	,,	33·2
			72·2	1	,,	,,	41·
72·078		0			,,	,,	42·0
			71·7	1	,,	,,	46·
			71·4	1	,,	,,	49·
			70·5	1	,,	,,	59·
69·825	69·82	3	69·9	1	,,	,,	65·9
69·220	69·18	4	69·2	6	,,	,,	72·5
69·005	69·00	5	69·0	6	,,	,,	74·6
68·507		1	68·6	1	,,	,,	79·8
			67·7	1	,,	,,	88·
			67·3	1	,,	,,	93·
66·760		0	66·5	1	,,	,,	98·4
66·167		0			,,	,,	32604·7
65·944		0	65·7	1	,,	,,	07·1
65·292	65·27	1			,,	,,	14·0
64·904		3	64·9	8	,,	,,	18·1
64·622	64·65	2			,,	,,	21·0
64·216		0	64·3	1	,,	,,	25·5
			61·6	2	0·86	,,	53·4
61·515	61·53	3	61·5	1	,,	,,	54·2
			61·1	1	,,	,,	59·
60·950	60·96	2			,,	,,	60·2
60·460		0	60·1	1	,,	,,	65·5
60·114		1			,,	,,	69·2
59·858		1	59·9	1	,,	,,	71·9
			58·8	1	,,	,,	83·
58·438		0	58·5	1	,,	,,	87·1
58·087		0			,,	,,	90·8
			57·7	1	,,	,,	95·0
57·590		2			,,	,,	96·3
57·398	57·40	4			,,	,,	98·2
			57·3	1	,,	,,	99·3
56·770		0			,,	,,	32705·0
			55·4	1n	,,	,,	20·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
3054·570		1			0·86	9·3	32728·5
54·351		0	3054·2	1	,,	9·4	30·8
53·709	3053·70·	2	53·7	1n	,,	,,	37·7
			53·2	1	,,	,,	43·
52·288	52·30	2	52·3	2	,,	,,	52·8
			51·5	1	,,	,,	61·
51·243	51·25	1	51·3	1	,,	,,	64·1
			50·6	1	,,	,,	71·
50·134		1	50·2	1	,,	,,	76·
49·559	49·52	5	49·4	1	,,	,,	82·4
48·783		1	48·9	1	,,	,,	89·6
47·904		1	48·0	1n	,,	,,	32800·0
47·277	47·27	5			,,	,,	06·8
45·768		0	45·7	1	,,	,,	23·8
			45·3	1	,,	,,	28·
44·255		0			,,	,,	39·4
43·671		0	43·6	1	,,	,,	45·7
42·760		2	42·7	8	,,	,,	55·5
42·429		0			,,	,,	59·1
41·979		1	42·0	1	,,	,,	63·9
			41·6	1	,,	,,	68·
41·056		1			,,	,,	73·9
			40·9	1	,,	,,	75·6
40·580	40·58	3			,,	,,	79·1
			40·0	1	,,	,,	85·
39·378	39·38	5	39·3	4	,,	,,	92·0
37·861	37·86	3	37·7	1	,,	,,	32908·5
			37·2	1	,,	,,	16·
36·361		0	36·5	1	,,	,,	25·8
			35·0	1	,,	,,	40·
34·675	34·66	2	34·6	1	,,	,,	43·1
			34·4	1	,,	,,	46·
			34·2	1	,,	,,	48·
33·744	33·75	2	33·7	1	,,	,,	53·1
			33·0	1	,,	,,	61·
32·528	32·55	2	32·6	1	,,	,,	66·3
30·568		0			,,	,,	87·7
30·365		1			,,	,,	89·9
29·487	29·50	5	29·5	2	,,	,,	99·4
26·489		1	26·5	4	,,	,,	33032·2
	25·99	3			,,	,,	37·6
			25·8	2	,,	,,	40·
			25·3	1	,,	9·5	45·
			25·0	1	,,	,,	48·
24·410		2	24·4	1	,,	,,	54·8
			23·4	1	,,	,,	66·
			23·2	1	,,	,,	68·
22·807	22·81	2	22·7	1	0·85	,,	72·3
22·536	22·54	2	22·5		,,	,,	75·3
			21·6		,,	,,	86·
			21·1		,,	,,	91·
			20·7		,,	,,	95·
20·125	20·12	3	20·1	1	,,	,,	33101·7
19·350	19·35	3	19·2	2	,,	,,	09·2

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda+$	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3018·151		2	3018·1	1n	0·85	9·5	33123·5
17·450	3017·43	4	17·4	1	,,	,,	31·2
			16·8	1	,,	,,	36·
16·550	16·55	3			,,	,,	40·9
			16·4	2	,,	,,	43·
			15·8	1	,,	,,	49·
			15·1	1	,,	,,	57·
14·854		1	14·9	1	,,	,,	59·6
14·585		1	14·6	1	,,	,,	62·5
			14·3	1	,,	,,	66·
			13·2	1	,,	,,	78·
12·984		1	13·0	1	,,	,,	80·2
12·695	12·71	2			,,	,,	83·3
			12·4	1	,,	,,	87·
11·812	11·84	3	11·7	1	,,	,,	92·9
10·020	10·03	2			,,	,,	33212·8
08·753		1	08·8	1	,,	,,	26·8
			08·5	1	,,	,,	30·
07·838		0			,,	,,	37·0
07·745		0	07·7	2	,,	,,	38·0
			06·5	1	,,	,,	52·
			06·3	1	,,	,,	54·
			05·7	1	,,	,,	61·
05·338	05·33	2			,,	,,	64·7
			05·1	1	,,	,,	67·
			04·7	1	,,	,,	72·
04·429		0			,,	,,	74·7
03·761	03·78	4	03·7	1	,,	,,	82·0
			03·2	1n	,,	,,	88·
02·375		1			,,	,,	97·5
			02·0	2	,,	,,	33302·
			01·6	1	,,	,,	06·
01·383		0			,,	,,	08·5
			01·2	1	,,	,,	10·
			01·0	1	,,	,,	12·
00·149	00·15	2	00·2	1	,,	,,	23·7
			2099·7	1	,,	,,	27·
2999·155		0	99·2	1n	,,	,,	33·2
			98·7	1	,,	,,	38·
			97·8	1	,,	,,	48·
	2997·54	3	97·6	2	,,	9·6	51·1
97·314	97·31	2	97·4	1	,,	,,	53·6
96·785		0			,,	,,	59·5
96·202	96·20	4			,,	,,	66·0
			95·5	1n	,,	,,	74·
			94·8	1	,,	,,	82·
			94·7	1	,,	,,	83·
93·751		0	93·8	1	,,	,,	93·3
			93·5	1	,,	,,	96·
93·184		2	93·2	1n	,,	,,	99·6
			91·9	1n	,,	,,	33414·
91·520		1	91·7	1n	,,	,,	18·2
90·746	90·77	3	90·7	1	,,	,,	26·7
			90·1	1	,,	,,	34·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
			2989·6	1	0·85	9·6	33440·
2988·335		0			,,	,,	53·8
			87·6	1	,,	,,	62·
			86·7	1	,,	,,	72·
85·921	2985·94	3	85·9	1	,,	,,	80·8
			83·8	1	,,	,,	33505·
			83·7	1 Fe ?	,,	,,	06·
82·962		0	82·9	1	0·84	,,	14·1
			82·7	1	,,	,,	17·
	82·55	1	82·5	1	,,	,,	18·8
		2	81·8	1	,,	,,	27·
81·042		2			,,	,,	35·7
80·776	80·80	4			,,	,,	38·6
80·578		0			,,	,,	40·9
80·375		0			,,	,,	43·2
			80·0	1	,,	,,	47·
			79·8	1	,,	,,	50·
			79·2	1	,,	,,	56·
			78·5	2	,,	,,	64·
			78·2	1	,,	,,	68·
78·056		2	78·0	1	,,	,,	69·3
	77·80	1	77·6	1	,,	,,	72·2
			77·3	1	,,	,,	78·
76·857		0			,,	,,	82·9
			76·4	1	,,	,,	88·
			75·6	1n	,,	,,	97·
75·062		4			,,	,,	33603·1
	75·07	3	75·1	2	,,	,,	03·0
74·659	74·66	1	74·6	1	,,	,,	07·7
74·220	74·24	2	74·3	1	,,	,,	12·5
			74·2	1	,,	,,	13·
			73·7	1	,,	,,	19·
72·646		0	72·5	1n	,,	,,	30·4
71·205	71·20	2	71·6	2	,,	,,	46·8
			69·7	1	,,	9·7	64·
	69·07	1	69·2	1	,,	,,	71·6
	68·60	1	68·7	1n	,,	,,	76·2
68·334	68·32	2	68·4	1	,,	,,	79·3
			67·8	1n	,,	,,	85·
67·360		0	67·4	1	,,	,,	90·3
			67·1	1	,,	,,	93·
66·245	66·24	2	66·3	1	,,	,,	33703·0
			65·7	1	,,	,,	09·
65·329	65·34	3	65·4	1	,,	,,	13·3
65·095		0			,,	,,	16·0
			64·3	2	,,	,,	25·
63·111	63·11	3	63·2	2	,,	,,	38·6
			63·1	1	,,	,,	39·
			62·7	1	,,	,,	43·
62·580		1			,,	,,	44·7
			61·8	1	,,	,,	54·
61·595	61·59	2	61·7	1	,,	,,	55·9
61·009	61·03	1	61·2	1	,,	,,	62·4
			60·3	2	,,	,,	70·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
2959·573		0			0·84	9·7	33778·9
			2959·2	1	,,	,,	83·
59·049		0			,,	,,	84·9
56·699		0	56·7	1	,,	,,	33811·8
			56·0	1	,,	,,	20·
			55·5	1n	,,	,,	26·
54·909		1	54·9	4	,,	,,	32·3
53·205		0	54·6	1 Fe?	,,	,,	52·
52·686		0	52·7	1n	,,	,,	57·8
51·363	2951·35	8	51·3	4	,,	,,	72·9
51·266		2			,,	,,	74·1
50·883	50·89	2			,,	,,	78·4
50·606	50·61	1	50·6	1	,,	,,	81·6
			50·4	1	,,	,,	84·
49·882	49·89	3	49·8	1	,,	,,	89·7
			48·5	1n	,,	,,	33906·
	47·48	1			,,	,,	17·6
47·093	47·10	3	47·1	2	,,	,,	22·0
			45·7	1	,,	,,	38·
			44·0	1	,,	9·8	58·
43·287	43·30	8	43·3	4	,,	,,	65·4
			42·7	1	0·83	,,	72·
41·197	41·20	2	41·2	1	,,	,,	90·0
40·669	40·66	3	40·7	2	,,	,,	96·1
40·548		0			,,	,,	97·5
39·390	39·40	3	39·4	4	,,	,,	34010·8
			39·2	1	,,	,,	13·
38·877	38·87	1			,,	,,	16·8
38·606	38·60	3			,,	,,	19·9
38·097		0			,,	,,	25·2
37·656		0			,,	,,	30·9
37·371		0	37·3	1	,,	,,	34·2
36·814	36·85	8	36·7	4	,,	,,	40·5
	36·20	1n	36·2	1	,,	,,	47·8
35·427		0			,,	,,	56·8
35·305	35·30	1	35·3	1	,,	,,	58·2
34·748	34·76	6	34·7	4	,,	,,	64·6
33·252	33·25	1	32·7	1	,,	,,	82·1
			32·7	1	,,	,,	88·
		0	32·2	1	,,	,,	94·
31·821		0			,,	,,	98·7
30·743	30·75	2	30·7	1	,,	,,	34111·2
30·298	30·30	1	30·3	1	,,	,,	16·4
			29·8	4	,,	,,	22·
27·833		0			,,	,,	45·1
			27·7	1	,,	,,	47·
27·129	27·14	1	27·1	1	,,	,,	53·3
			26·7	1	,,	,,	58·
26·212		0	26·2	1	,,	,,	64·1
			25·2	4	,,	,,	76·
24·912	24·94	10	24·9	4	,,	,,	79·1
			24·0	1	,,	,,	90·
21·237		0	21·3	2	,,	9·9	34222·2
			20·9	1	,,	,,	26·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2919·9	1	0·83	9·9	34238·
2919·299		0	19·3	4	,,	,,	44·9
18·683	2918·69	3	18·7	4	,,	,,	52·1
			18·1	1	,,	,,	59·
17·885	17·86	1	17·9	1	,,	,,	61·6
			16·8	1	,,	,,	74·
16·479	16·49	4	16·4	4	,,	,,	78·0
15·793		0	15·7	1	,,	,,	86·1
15·625		0			,,	,,	88·1
			14·1	2	,,	,,	34306·
			13·9	1	,,	,,	08·
			13·7	1	,,	,,	11·
13·592		0			,,	,,	12·0
	12·36	1 Pt?	12·4	1	,,	,,	26·5
			11·4	1	,,	,,	38·
			10·7	1n	,,	,,	46·
09·912		0			,,	,,	55·4
09·669	09·66	2	09·6	1	,,	,,	58·3
			08·8	1	,,	,,	68·
			08·4	1	,,	,,	73·
			07·7	1n	,,	,,	81·
07·353	07·36	3	07·3	1	,,	,,	85·6
			06·5	1n	,,	,,	96·
			06·0	1	,,	,,	34402·
05·774	05·75	2	05·7	1	,,	,,	04·5
04·913	04·93	4	04·9	1	,,	,,	14·5
03·995		0			,,	,,	25·4
03·852		0	03·7	1n	0·82	,,	27·1
			03·4	1n	,,	,,	32·
02·430		0			,,	,,	44·1
	02·09	3	01·9	1	,,	,,	48·0
			01·2	1	,,	,,	59·
00·492	00·50	1	00·4	1	,,	,,	68·0
00·165		0			,,	,,	70·9
2899·733	2899·74	2	2899·6	1	,,	,,	76·0
99·055		0			,,	,,	84·1
98·455		2	98·5	1n	,,	,,	91·2
			98·0	1	,,	,,	97·
97·783		0			,,	,,	99·2
97·260	97·27	5	97·1	2	,,	,,	34505·4
	97·07	1			,,	10·0	07·6
95·705		0	95·7	1	,,	,,	23·9
94·388		0			,,	,,	39·6
			94·0	1	,,	,,	44·2
93·785		0			,,	,,	46·8
92·371		1	92·3	1	,,	,,	63·7
			91·7	1	,,	,,	72·
90·634		0			,,	,,	84·5
89·688		1	89·7	1	,,	,,	95·8
			88·3	1	,,	,,	34612·
87·240		2			,,	,,	25·1
			86·9	1	,,	,,	29·
85·615		0			,,	,,	44·7
			85·4	1b	,,	,,	47·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	1/λ −	
			2884·7	1	0·82	10·0	34656·
			84·2	1	,,	,,	62·
2883·549	2883·55	1	83·5	1	,,	,,	69·5
82·970		0			,,	,,	76·
82·742	82·77	5	82·6	1	,,	,,	79·0
			82·2	1	,,	,,	86·
			81·7	1	,,	,,	92·
81·270	81·30	2	81·1	1	,,	,,	96·7
80·324	80·29	1	80·2	1	,,	,,	34708·5
80·174		0	80·1	1	,,	,,	10·1
79·878		0			,,	,,	13·7
79·515	79·51	3	79·5	1	,,	,,	18·1
78·632		2	78·7	1n	,,	,,	28·7
77·781	77·79	4	77·7	1	,,	,,	38·9
77·108		0	77·1	1	,,	,,	47·1
76·096	76·10	4	76·1	2	,,	,,	59·3
75·721	75·72	4	75·7	2	,,	,,	63·9
	75·10	1			,,	,,	71·4
73·929		0	73·8	1	,,	,,	85·6
	73·46	2	73·4	1	,,	,,	91·2
72·227		0			,,	,,	348062·
			71·9	1	,,	,,	10·
			71·7	1	,,	,,	13·
			71·2	1	,,	,,	19·
			71·1	1	,,	,,	20·
70·698		0			,,	,,	24·8
70·304		0	70·2	1n	,,	,,	29·5
69·815	69·80	2			,,	,,	35·5
			69·6	1	,,	,,	38·
	68·70	1			,,	10·1	48·9
			67·8	1	,,	,,	60·
66·798	66·76	3	66·7	1	,,	,,	72·3
			65·6	1	,,	,,	87·
63·955	63·95	3			0·81	,,	34906·7
			62·8	1	,,	,,	21·
	62·60	1	62·6	1	,,	,,	23·2
62·455	62·49	1n			,,	,,	24·7
			61·0	1n	,,	,,	43·
60·767	60·77	2	60·7	1	,,	,,	45·5
			60·4	1	,,	,,	50·
60·126		0			,,	,,	53·4
			60·0	1	,,	,,	55·
			59·4	1	,,	,,	62·
59·138		0			,,	,,	65·5
			58·9	1	,,	,,	68·
			58·5	1 Fe ?	,,	,,	73·
57·058	57·05	1	57·0	1	,,	,,	91·0
56·048	56·03	1	56·1	1n	,,	,,	35003·4
55·931	55·96	1			,,	,,	04·6
			55·7	1	,,	,,	08·
			55·5	1	,,	,,	10·
54·722		0			,,	,,	19·6
53·416	53·43	1	53·5	1	,,	,,	35·5
52·605		0	52·6	1	,,	,,	45.6

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2852·3	1	0·81	10·1	35049·
2851·648	2851·65	1n	51·6	1	,,	,,	57·3
51·518	51·56	1n			,,	,,	58·7
51·161		0	50·8	1	,,	,,	63·3
50·906		0			,,	,,	66·5
			50·5	1n	,,	,,	81·
49·848	49·86	8	49·7	6	,,	,,	79·4
49·557		0			,,	,,	83·1
48·557		0	48·4	1	,,	,,	95·4
46·753		0	46·8	1	,,	10·2	35117·5
			46·5	1	,,	,,	21·
			46·3	1	,,	,,	23·
45·245		1			,,	,,	36·0
45·009		0	44·6	1	,,	,,	39·2
42·390	42·40	2			,,	,,	71·4
			42·1	1	,,	,,	75·
41·798	41·80	1			,,	,,	78·8
			41·6	1	,,	,,	81·
40·332	40·35	4			,,	,,	96·8
			40·2	4	,,	,,	99·
39·287	39·32	6			,,	,,	35209·7
			39·2	4	,,	,,	11·
			38·3	1n	,,	,,	21·
37·421	37·42	3			,,	,,	33·1
			37·2	2	,,	,,	36·
36·506	36·51	4			,,	,,	44·4
36·197	36·21	1			,,	,,	48·2
35·762	35·75	3	35·7	1	,,	,,	53·8
35·408					,,	,,	58·1
		0	34·2	1	,,	,,	73·1
33·777		0			,,	,,	78·4
33·337	33·35	3	33·2	8	,,	,,	83·8
32·874		2	32·6	1	,,	,,	89·6
31·912	31·93	1	31·8	1	,,	,,	35301·5
31·455	31·46	1			,,	,,	07·3
30·964					,,	,,	13·4
30·601	30·57	2	30·4	1n	,,	,,	18·2
30·264		3			,,	,,	21·2
29·720	29·73	1	29·8	1	,,	,,	28·9
27·259	27·27	1	27·2	1	,,	,,	59·7
26·316		0	26·3	1n	,,	,,	71·6
			25·7	1	,,	,,	79·
			25·5	1	,,	,,	82·
24·546	24·59	6	24·4	2	0·80	,,	93·4
24·228		1			,,	,,	97·7
23·831		0	23·7	1	,,	,,	35402·7
23·280	23·34	4	23·3	1	,,	10·3	09·1
20·738		2	20·6	1	,,	,,	41·4
20·614		0			,,	,,	43·0
19·848		0	19·8	1n	,,	,,	52·4
			19·3	1	,,	,,	60·
			17·6	1	,,	,,	81·
17·284		0			,,	,,	84·9
17·039	17·04	1	17·0	1	,,	,,	88·4

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda}-$	
2816·409		0	2816·5	1	0·80	10·3	35495·9
15·744		0	15·9	1	,,	,,	35504·3
			15·5	1n	,,	,,	07·
14·966	2815·00	1	15·0	1	,,	,,	14·1
14·532	14·52	1	14·5	1	,,	,,	19·8
			14·1	1	,,	,,	26·
			13·6	1	,,	,,	31·
			13·3	1	,,	,,	35·
12·896	12·91	2	12·7	1	,,	,,	40·2
			12·0	2	,,	,,	52·
			11·4	1	,,	,,	59·
			11·3	1n	,,	,,	60·
10·657	10·65	1	10·5	1	,,	,,	68·6
			08·7	1	,,	,,	93·
08·249		0	08·1	1	,,	,,	99·1
07·754	07·75	1	07·6	1	,,	,,	35605·4
06·772		0			,,	,,	17·8
06·479	06·50	1	06·3	1b	,,	,,	21·4
			05·8	1b	,,	,,	30·
04·300		0	04·6	2	,,	,,	49·2
			03·2	1	,,	,,	63·
			02·7	2	,,	,,	70·
			01·9	1	,,	,,	80·
			01·5	1	,,	,,	85·
			01·1	1	,,	,,	90·
00·923	00·91	3			,,	,,	92·3
00·755		1	00·6	4	,,	,,	94·4
2799·835	2799·84	2	2799·6	1	,,	,,	35706·1
99·522		0			,,	10·4	10·0
			99·3	1	,,	,,	13·
			98·7	1n	,,	,,	20·
98·283	98·29	4	98·1	2	,,	,,	25·7
	97·82	5	97·6	2n	,,	,,	31·7
97·456	97·45	4	97·3	2	,,	,,	36·5
96·558	96·55	2	96·3	1	,,	,,	47·9
			95·7	1n	,,	,,	59·
			95·4	2	,,	,,	63·
94·189	94·20	1			,,	,,	78·1
93·907		0	93·6	2n	,,	,,	85·7
			92·2	1	,,	,,	35804·
			91·4	1n	,,	,,	14·
90·795		0	90·6	1	,,	,,	21·7
			90·2	1	,,	,,	29·
			89·7	1	,,	,,	36·
			89·4	1n	,,	,,	40·
89·066		0	89·1	1	,,	,,	43·9
			88·5	1n	,,	,,	51·
87·687		0	87·8	1	,,	,,	61·6
			87·4	1	,,	,,	65·
87·099		1			,,	,,	69·2
			86·3	1	,,	,,	79·
			85·9	1	,,	,,	85·
			85·6	1	,,	,,	89·
85·319	85·33	3			,,	,,	92·1

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2785·2	1	0·80	10·4	35894·
2783·797		0			0·79	,,	35911·8
83·492		0	83·5	1	,,	,,	15·7
			83·1	1	,,	,,	21·
82·885		0			,,	,,	23·5
			82·5	1n	,,	,,	27·5
82·342		0			,,	,,	30·5
			81·7	1	,,	,,	39·
81·401	2781·42	4	81·3	2	,,	,,	42·6
81·047	81·07	1	81·0	1	,,	,,	47·1
80·507	80·55	1			,,	,,	54·0
79·752		1	79·3	1	,,	,,	69·9
			78·6	1	,,	,,	79·
			76·0	1	,,	,,	87·
77·645					,,	,,	91·3
77·536	77·55	2	77·4	1	,,	,,	92·6
77·149					,,	,,	97·7
			76·3	1	,,	,,	36009·
75·646	75·65	3	75·5	2	,,	,,	17·2
75·073	75·09	1	74·9	6	,,	10·5	24·5
74·685	74·73	1			,,	,,	29·3
	74·05	1	73·8	1	,,	,,	37·9
			73·5	1	,,	,,	45·
			73·0	1	,,	,,	52·
72·547	72·58	3	72·5	1	,,	,,	57·2
71·711	71·76	3			,,	,,	67·0
			69·6	1	,,	,,	96·
			69·3	1	,,	,,	36100·
			68·8	1	,,	,,	06·
			68·5	1	,,	,,	10·
67·764	67·76	1	67·6	1	,,	,,	19·8
67·423	67·47	2					23·9
			66·9	1	,,	,,	31·
			66·3	1	,,	,,	39·
			65·9	1	,,	,,	44·
			65·4	1	,,	,,	51·
			65·2	1	,,	,,	53·
			64·8	1	,,	,,	58·
			64·1	1	,,	,,	68·
			63·9	1	,,	,,	70·
			63·5	1	,,	,,	76·
63·287		0	63·3	2	,,	,,	78·3
			62·7	2	,,	,,	86·
			62·1	1n	,,	,,	94·
61·700		0			,,	,,	99·1
61·227		0	61·3	1n	,,	,,	36205·3
60·474		0			,,	,,	15·2
60·207		0	60·6	1	,,	,,	18·7
60·009	60·00	2			,,	,,	21·4
			59·8	1	,,	,,	24·
59·405	59·42	2	59·4	1	,,	,,	29·1
59·100	59·11	1n			,,	,,	33·5
			58·8	1n	,,	,,	37·
			58·4	1	,,	,,	42·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
2758·325	2758·33	2			0·79	10·5	36243·4
			2758·2	1	,,	,,	45·
			57·6	1	,,	,,	53·
			56·6	1	,,	,,	66·
56·206	56·20	1			,,	,,	71·3
			56·0	1	,,	,,	74·
			55·8	1	,,	,,	77·
			55·2	1	,,	,,	85·
			54·6	1	,,	,,	92·
53·954		0	53·8	2	,,	,,	36300·9
			53·2	1	,,	,,	11·
			52·8	2	,,	,,	16·
			52·3	1	,,	,,	23·
			51·8	1	,,	,,	29·
			50·8	1	,,	10·6	43·
			50·0	1n	,,	,,	53·
			49·3	1	,,	,,	62·
49·075		0			,,	,,	65·3
			48·8	1	,,	,,	69·
48·395		0	48·3	1	,,	,,	74·3
			48·0	1	,,	,,	80·
47·602	47·62	1			,,	,,	94·7
47·383		0			,,	,,	87·7
			46·1	1	,,	,,	36405·
			45·5	1	,,	,,	13·
			45·2	1	,,	,,	17·
			44·5	1	,,	,,	26·
44·091	44·09	3	44·1	2	,,	,,	31·3
43·769		0	43·9	1	,,	,,	35·6
43·477		0	43·5	2	,,	,,	39·5
40·432		1			0·78	,,	80·0
40·267	40·22	1			,,	,,	82·5
40·166	40·16	1			,,	,,	83·6
40·085	40·08	1			,,	,,	84·7
39·413	39·39	1	39·4	2	,,	,,	93·7
			39·3	1	,,	,,	95·
38·875		0	38·7	1	,,	,,	36500·7
			38·4	1	,,	,,	07·
			37·6	1n Rh ?	,,	,,	18·
	37·38§	2	37·3	1	,,	,,	20·7
			36·8	1	,,	,,	28·
36·509		0			,,	,,	32·3
			36·3	1	,,	,,	35·
	35·78	1n	35·7	1	,,	,,	42·1
			35·3	1	,,	,,	48·
35·165		1			,,	,,	50·3
			35·0	1n	,,	,,	52·
34·596		0			,,	,,	58·1
			34·3	1	,,	,,	62·
	34·03″	5			,,	,,	65·4
			33·4	2	,,	,,	74·

§ Occurs also in Pt.
″ Occurs also in Pt and Pd.

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2732·752	2732·75	2			0·78	10·6	36582·6
			2732·5	4	,,	,,	86·
31·954		0			,,	,,	93·2
			31·2	1	,,	,,	36603·
			31·1	1	,,	,,	05·
	30·79	2			,,	,,	08·8
30·500		0			,,	,,	12·7
29·638	29·64	1	29·6	1	,,	,,	24·3
			28·8	1	,,	,,	35·
			28·6	1	,,	,,	38·
28·494		1			,,	,,	39·6
28·224		0			,,	,,	43·2
			28·0	1	,,	,,	46·
			27·6	2	,,	,,	51·
			26·9	1	,,	10·7	61·
26·566	26·56	1	26·6	1	,,	,,	65·5
			25·6	1	,,	,,	78·
			25·3	1	,,	,,	83·
24·884		0	24·8	1	,,	,,	88·1
23·849	23·85	2			,,	,,	36702·1
	23·68	2	23·7	1	,,	,,	04·3
23·248		0	23·3	1	,,	,,	10·2
			22·7	1	,,	,,	18·
			22·3	1	,,	,,	23·
21·443		0			,,	,,	34·5
			20·9	1n	,,	,,	42·
20·534	20·55	2	20·4	1	,,	,,	46·7
19·906		0			,,	,,	55·3
			18·9	1	,,	,,	69·
			18·6	1n	,,	,,	73·
17·730		0			,,	,,	84·7
16·612		0	16·6	1	,,	,,	99·9
			16·5	1	,,	,,	36801·
			16·1	1n	,,	,,	07·
			15·2	1	,,	,,	19·
		1			,,	,,	26·5
14·643	13·95	1	14·1	4	,,	,,	35·9
13·195		1			,,	,,	46·2
12·817	12·82	3	12·8	1	,,	,,	52·7
			12·3	1	,,	,,	58·
			12·0	1	,,	,,	62·
11·402		0	11·6	1	,,	,,	70·6
			10·8	1	,,	,,	79·
			10·6	1	,,	,,	81·
10·177	10·18	1	10·3	1	,,	,,	87·2
			09·5	1	,,	,,	96·
			09·2	1	,,	,,	36900·
			08·8	1	,,	,,	06·
08·752		0	08·7	2	,,	,,	06·7
			07·9	1	,,	,,	18·
			07·7	1	,,	,,	21·
07·265		0	07·3	1	,,	,,	26·9
06·985		0	07·1	1	,,	,,	30·8
05·632	05·65	1	05·5	1	,,	,,	49·1

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2705·453		0			0·78	10·7	36951·7
05·296					,,	,,	53·8
05·213	2705·21	1n			,,	,,	55·0
	05·02	1	2705·1	1	,,	,,	57·8
			04·8	1n	,,	,,	61·
04·722		0			,,	,,	61·7
04·117	04·12	2	04·0	1	,,	,,	69·9
			02·8	1	,,	,,	88·
			01·7	1	,,	10·8	37003·
			01·4	1	,,	,,	07·
01·200	01·21	1n			,,	,,	09·7
			01·1	1	,,	,,	11·
			00·5	1	,,	,,	19·
2698·688		2	2698·7	1	0·77	,,	44·2
			98·1	1	,,	,,	52·
			97·5	1	,,	,,	60·
			97·2	1	,,	,,	64·
			96·9	1	,,	,,	69·
96·010	96·04	1			,,	,,	80·8
95·550	95·57	1n	95·6	1	,,	,,	87·2
			95·1	1	,,	,,	94·
94·320	94·33	5	94·3	2	,,	,,	37104·2
93·571	93·60	1	93·5	1	,,	,,	13·8
			93·4	1	,,	,,	17·
92·964	92·99	1			,,	,,	22·8
			92·8	1n	,,	,,	25·
92·429	92·45	3b[r]	92·4	1	,,	,,	30·2
92·267		0	92·2	1	,,	,,	32·6
91·998		0			,,	,,	36·3
			91·5	1	,,	,,	43·
91·154	91·19	1			,,	,,	47·7
			90·7	2	,,	,,	54·
89·769		0			,,	,,	67·3
88·381		0	88·2	1	,,	,,	86·3
			87·6	1	,,	,,	97·
			87·1	1	,,	,,	37204·
			86·8	1	,,	,,	08·
			86·3	1	,,	,,	15·
			85·7	1	,,	,,	23·
			85·1	1	,,	,,	32·
			84·8	1	,,	,,	36·
	84·15	2	84·0	2	,,	,,	44·9
83·387		0	83·2	1	,,	,,	55·5
			82·8	1	,,	,,	64·
82·536	82·55	1	82·6	1	,,	,,	67·3
			82·2	1	,,	,,	72·
81·184	81·22	1	81·3	1	,,	,,	85·9
			80·5	1	,,	,,	96·
			80·1	1	,,	,,	37301·
79·506	79·51	1	79·3	1	,,	,,	09·5
	79·17	2			,,	,,	13·2
			78·7	1	,,	10·9	21·
			78·3	1	,,	,,	26·
77·899		0	77·7	1	,,	,,	31·8

IRIDIUM—*continued*.

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2676·911	2676·93	2	2676·7	1	0·77	10·9	37345·5
			76·2	1	,,	,,	55·
			75·7	1	,,	,,	62·
75·376		0	75·4	1	,,	,,	67·0
			75·2	1	,,	,,	69·
			74·3	1	,,	,,	82·
73·694	73·70	3	73·8	1	,,	,,	90·5
			73·5	2	,,	,,	93·
72·888		0	73·0	1	,,	,,	37401·8
71·930	71·93	4	71·9	1	,,	,,	15·2
70·006	70·01	4	70·0	1	,,	,,	42·2
	69·56	1	69·5	1	,,	,,	48·5
69·070	69·09	2	69·0	1	,,	,,	55·2
			68·5	1	,,	,,	63·
68·362		0			,,	,,	
			68·2	1	,,	,,	67·
			67·9	1	,,	,,	72·
67·540	67·54	1	67·5	1	,,	,,	76·8
			66·6	1	,,	,,	90·
	66·50	1			,,	,,	91·4
			66·4	1	,,	,,	93·
			65·7	1	,,	,,	37502·
65·144		0			,,	,,	10·5
64·871	64·87	5	64·9	2	,,	,,	14·4
			64·6	2	,,	,,	18·
63·400	63·42	2	63·5	1	,,	,,	34·9
62·706	62·71	3	62·7	1	,,	,,	44·8
62·080	62·10	5	62·2	1	,,	,,	53·6
			61·7	1	,,	,,	59·
			61·3	2	,,	,,	65·
60·163		0			,,	,,	80·8
60·040		0			,,	,,	82·5
			59·7	1n	,,	,,	87·
			58·3	1n	,,	,,	37607·
57·993		0			,,	,,	11·5
57·799	57·82	1	57·7	1	,,	,,	14·2
			57·6	1	,,	,,	17·
56·898	56·91	2	56·8	1	,,	,,	26·4
			56·2	1	,,	,,	37·
			56·1	1	,,	,,	38·
			55·7	1n	,,	,,	44·
54·670		0	54·7	1n	0·76	11·0	58·6
54·033	54·05	2	53·9	1	,,	,,	67·5
53·853	53·86	2	53·9	1	,,	,,	70·1
			53·7	1	,,	,,	72·
			53·2	1	,,	,,	79·
53·124	53·13	1			,,	,,	80·5
			53·0	1	,,	,,	82·
	52·76	1n			,,	,,	85·6
	52·60	1n			,,	,,	87·9
			52·1	1	,,	,,	95·
			51·8	1	,,	,,	99·
			51·4	1	,,	,,	37705·
			50·7	1	,,	,,	15·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2650·584		0	2650·5	1	0·76	11·0	37716·5
			50·2	1	,,	,,	22·
			49·7	1n	,,	,,	29·
			48·7	1	,,	,,	43·
			48·4	1	,,	,,	48·
			47·3	1n	,,	,,	63·
			46·8	1	,,	,,	70·
46·334	2646·35	1			,,	,,	77·0
			46·1	1	,,	,,	80·
			45·8	1	,,	,,	85·
			45·7	1	,,	,,	86·
			45·3	1	,,	,,	92·
			44·5	1	,,	,,	37803·
44·279	44·28	2			,,	,,	06·4
			44·1	1	,,	,,	09·
			43·5	1n	,,	,,	18·
			43·3	1n	,,	,,	20·
			41·5	1	,,	,,	46·
			41·0	1	,,	,,	53·
40·462	40·45	1	40·4	1	,,	,,	62·2
	39·80	4	39·8	4	,,	,,	70·7
39·510	39·51	2	39·4	1	,,	,,	74·8
39·073	39·06	1			,,	,,	81·2
			38·7	1	,,	,,	86·
			38·3	1	,,	,,	92·
			37·8	1	,,	,,	99·
			37·5	1	,,	,,	37904·
37·407		0			,,	,,	05·0
			37·3	1	,,	,,	07·
36·967		0			,,	,,	11·4
			36·7	1	,,	,,	15·
			36·4	1	,,	,,	20·
			35·7	1	,,	,,	30·
35·353	35·35	2			,,	,,	34·6
			35·1	1	,,	,,	38·
34·513		0			,,	,,	46·7
34·340	34·33	3	34·2	2	,,	,,	55·2
			33·1	1	,,	,,	67·
			30·5	1	,,	11·1	38004·
			30·0	1	,,	,,	12·
29·498	29·49	1	29·4	1	,,	,,	19·0
			29·1	1	,,	,,	25·
			28·7	1	,,	,,	31·
28·271		0			,,	,,	36·7
			28·0	1	,,	,,	41·
			27·1	1	,,	,,	54·
26·844	26·85	2			,,	,,	57·4
			25·6	1	,,	,,	76·
25·396	25·43	2			,,	,,	78·1
			24·6	1	,,	,,	90·
			24·1	1	,,	,,	97·
23·736	23·75	1n			,,	,,	38102·4
			23·5	1	,,	,,	06·
			23·0	1	,,	,,	13·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2622·203		0			0·76	11·1	38124·8
21·610		0	2621·6	1	,,	,,	33·4
			21·1	1	,,	,,	41·
			20·6	1	,,	,,	48·
20·102	2620·00	2			,,	,,	56·1
19·967		2	19·9	1	,,	,,	57·3
			18·7	1b	,,	,,	76·
18·352		0			,,	,,	80·5
17·872	17·86	3	17·8	1	,,	,,	87·8
17·514		0			,,	,,	93·1
17·177		0	17·1	2	,,	,,	98·0
			16·3	1	,,	,,	38211·
			16·2	1	,,	,,	12·
16·090	16·08	1			,,	,,	14·0
	16·00	1	15·8	1	,,	,,	15·2
			15·5	1	,,	,,	23·
15·064	15·06	2	15·1	1	,,	,,	28·9
			14·9	1	,,	,,	31·
14·287	14·27	1	14·1	1	,,	,,	40·4
			13·7	1	,,	,,	49·
12·344	12·35	1	12·2	1	,,	,,	68·6
12·136	12·13	1	12·2	1	,,	,,	71·8
			11·8	1	,,	,,	77·
11·384	11·40	3	11·4	2	,,	,,	82·7
			10·5	1n	,,	,,	96·
10·198		0	10·0	1	0·75	,,	38300·2
09·996		0			,,	,,	03·1
			09·8	1	,,	,,	06·
08·314	08·30	3			,,	11·2	27·8
			08·1	2	,,	,,	31·
07·608	07·60	2			,,	,,	38·2
			07·3	1	,,	,,	43·
			07·0	1	,,	,,	47·
06·668		0			,,	,,	51·9
			06·4	2	,,	,,	56·
06·081		0			,,	,,	60·5
04·645	04·64	1			,,	,,	81·7
			04·5	1	,,	,,	84·
			04·1	1	,,	,,	90·
			03·8	1n	,,	,,	94·
			02·8	1	,,	,,	38409·
02·122	02·15	1			,,	,,	18·8
			02·0	1	,,	,,	21·
			00·9	1	,,	,,	37·
			00·7	1	,,	,,	40·
2599·224		0	2599·4	2	,,	,,	61·8
99·129	2599·15	2			,,	,,	63·1
			99·0	2	,,	,,	65·
			98·3	2	,,	,,	76·
			97·5	1	,,	,,	86·
95·914	95·93	1n			,,	,,	38510·8
			95·7	4	,,	,,	14·
95·188		0	95·2	1	,,	,,	21·7
			94·6	1	,,	,,	30·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2593·224		1			0·75	11·2	38550·8
			2593·0	1	,,	,,	54·
			92·7	1	,,	,,	59·
92·146	2592·15	3	92·0	2	,,	,,	66·8
91·927		1			,,	,,	70·1
			91·5	1	,,	,,	76·
91·129		1			,,	,,	82·0
			91·0	2	,,	,,	84·
			90·5	1	,,	,,	91·
90·296		0			,,	,,	94·4
			90·1	1	,,	,,	97·
			89·6	1	,,	,,	38605·
89·470		0			,,	,,	06·7
89·231		0			,,	,,	10·3
89·057		0	89·1	1	,,	,,	12·9
			88·5	1	,,	11·3	21·
			87·5	1	,,	,,	36·
			87·1	1	,,	,,	42·
86·146	86·14	1	86·0	8	,,	,,	56·3
84·867		0	84·8	1	,,	,,	75·4
			83·6	1	,,	,,	94·
83·261	83·26	1	83·0	1	,,	,,	99·5
			81·8	1	,,	,,	38721·
81·523		0			,,	,,	25·5
81·019		0	81·2	1	,,	,,	33·1
79·860		0			,,	,,	50·5
79·573		2	79·6	6	,,	,,	54·8
			79·4	6	,,	,,	57·
79·008	79·00	2			,,	,,	63·4
78·794	78·78	2	78·8	1	,,	,,	66·6
			78·6	1	,,	,,	69·
			78·2	1	,,	,,	75·
77·622		0	77·8	1	,,	,,	84·1
	77·35	3			,,	,,	88·2
			75·2	1	,,	,,	38821·
			74·5	1	,,	,,	31·
			74·2	1	,,	,,	36·
73·338		0	73·5	1	,,	,,	48·7
72·784	72·79	2	72·7	2	,,	,,	57·0
72·459	72·47	1	72·5	1	,,	,,	61·9
72·156	72·16	1	72·2	1	,,	,,	67·6
			71·9	1	,,	,,	70·
	70·70	1			,,	,,	88·6
			70·5	1	,,	,,	91·6
69·962	69·97	2			,,	,,	99·7
68·407		0	68·6	1	,,	,,	38923·3
			68·1	1	,,	,,	28·
			67·6	1	,,	,,	35·
			67·0	1	,,	,,	45·
			66·7	1	,,	,,	49·
66·442		0			,,	,,	53·1
			66·2	1n	,,	,,	57·
			65·3	1n	,,	,,	70·
64·922		0			0·74	,,	76·1

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2564·4	1	0·74	11·3	38984·1
2564·253	2564·27	2			,,	,,	86·5
			64·0	2	,,	,,	90·
63·365	63·36	1	63·3	1n	,,	,,	99·9
62·999		0			,,	,,	39005·3
			62·8	2	,,	,,	08·
			62·5	1	,,	,,	13·
			61·8	1	,,	,,	24·
			61·7	1	,,	,,	25·
			61·1	2	,,	,,	34·
			60·1	1n	,,	,,	50·
59·643		0			,,	,,	56·5
			59·2	1	,,	,,	63·
58·821		0			,,	,,	69·1
			58·3	4	,,	,,	77·
			57·7	1	,,	,,	86·
57·285		0	57·2	1	,,	,,	92·6
56·860		1			,,	,,	99·1
			56·5	1	,,	,,	39104·6
55·955	55·95	1			,,	,,	13·0
			55·6	1	,,	,,	18·
55·425		2			,,	,,	21·0
			55·1	1	,,	,,	26·
54·480	54·47	2			,,	,,	35·6
			54·1	4	,,	,,	41·
			53·6	1	,,	,,	49·
51·475	51·50	2			,,	,,	81·4
			51·2	1	,,	,,	86·
50·987		0			,,	,,	89·[illegible]
			49·4	1	,,	,,	39214·
			49·3	1	,,	,,	15·
			49·0	1	,,	11·5	20·
			48·0	1	,,	,,	35·
	47·76	1	47·6	1	,,	,,	38·7
			47·5	1	,,	,,	41·
47·278	47·26	1	47·2	1n	,,	,,	46·2
45·868		0	45·9	1	,,	,,	67·8
45·620	45·62	1			,,	,,	71·7
			44·4	1	,,	,,	91·
44·059	44·08	4			,,	,,	95·6
			43·9	2	,,	,,	98·
			43·5	1	,,	,,	39304·
			43·2	1	,,	,,	09·
			42·7	1	,,	,,	17·
42·097	42·11	2			,,	,,	26·0
			41·7	1	,,	,,	32·
41·556	41·56	1			,,	,,	34·6
			41·3	1	,,	,,	38·
			40·8	1	,,	,,	46·
40·483	40·49	1	40·5	1	,,	,,	51·1
			40·3	1	,,	,,	54·
			39·6	1	,,	,,	65·
38·949		0			,,	,,	74·9
			38·7	1	,,	,,	79·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
2538·548		0			0·74	11·5	39381·1
			2538·2	1	,,	,,	86·
37·770	2537·78	1			,,	,,	93·1
			37·6	1	,,	,,	96·
37·309	37·30	2			,,	,,	39400·4
			37·1	1	,,	,,	04·
36·760		0	36·7	1	,,	,,	08·9
			36·2	1	,,	,,	18·
			36·0	1	,,	,,	21·
			35·3	1n	,,	,,	32·
34·103		0	34·2	2	,,	,,	50·2
			33·7	1	,,	,,	56·
			33·4	1	,,	,,	61·
	33·24	3			,,	,,	63·6
			33·0	2	,,	,,	67·
	32·63	1			,,	,,	73·1
32·290	32·29	1n	32·3	1	,,	,,	78·4
			32·0	1	,,	,,	83·
			31·7	1	,,	,,	88·
			31·1	1	,,	,,	97·
30·786		0	30·8	1	,,	,,	39502·1
30·498		0	30·4	2	,,	,,	06·4
30·200		0			,,	11·6	11·0
29·870		0			,,	,,	16·1
29·559	29·56	2	29·6	1	,,	,,	21·0
			29·4	1	,,	,,	23·
			28·4	2	,,	,,	39·
28·011		0			,,	,,	45·1
27·868		0	27·7	1	,,	,,	47·4
			27·4	1	,,	,,	55·
26·856		0	26·7	1	,,	,,	63·1
			26·5	1	,,	,,	69·
			25·7	4	,,	,,	81·
			25·3	1	,,	,,	88·
	25·16	1	25·1	1	,,	,,	89·8
24·953	24·99	1	24·9	1	,,	,,	93·1
			23·9	1	,,	,,	39610·
			23·7	1	,,	,,	13·
23·290		0			,,	,,	19·1
			22·8	1	,,	,,	27·
			21·7	1	,,	,,	44·
21·175		0	21·2	2	,,	,,	52·4
			19·9	1	,,	,,	73·
			19·5	1	,,	,,	79·
			19·1	1	,,	,,	85·
			18·6	1	,,	,,	93·
			18·1	2	,,	,,	39701·
			17·8	2	0·73	,,	06·
15·448	15·45	1	15·4	1	,,	,,	42·7
13·799	13·80	2			,,	,,	69·8
			13·6	1	,,	,,	72·
			13·2	1	,,	,,	78·
12·665	12·66	2	12·5	8	,,	,,	86·8
12·191		0			,,	,,	94·3

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2512·096	2512·02	1	2512·0	4	0·73	11·6	39797·0
09·798	09·80	1	09·7	1	,,	11·7	39832·1
08·434	08·42	1	08·3	1	,,	,,	53·9
07·712	07·70	1	07·6	1	,,	,,	65·4
			07·0	1	,,	,,	76·
	06·70	1			,,	,,	81·4
			06·5	1	,,	,,	85·
			06·2	1	,,	,,	89·
05·814	05·82	1			,,	,,	95·4
05·308		0			,,	,,	39903·5
04·446	04·44	1			,,	,,	17·3
03·063	03·08	3			,,	,,	39·2
02·710	02·72	2	02·7	1	,,	,,	44·9
			01·0	1	,,	,,	72·
00·357	00·36	1	00·2	1	,,	,,	82·6
			2499·5	1n	,,	,,	96·
	2499·36				,,	,,	98·5
			98·4	1	,,	,,	40014·
			97·9	2	,,	,,	22·
			97·0	1n	,,	,,	36·
2496·360		2	96·3	1	,,	,,	46·6
95·951		0			,,	,,	53·2
			94·9	1	,,	,,	70·
			94·4	1	,,	,,	78·
			94·2	1	,,	,,	82·
			93·6	1	,,	11·8	91·
93·163	93·16	2	93·2	1	,,	,,	97·9
92·406		0	92·3	1	,,	,,	40110·1
91·778		0			,,	,,	20·2
			89·6	1	,,	,,	55·
			89·4	1	,,	,,	58·
89·293		0	89·2	1	,,	,,	60·2
88·325		0n	88·4	4	,,	,,	75·8
			87·6	1	,,	,,	88·
			87·1″	1	,,	,,	96·
86·826		0			,,	,,	40200·1
86·463		0	86·3	1	,,	,,	06·0
			85·9	1	,,	,,	15·
	85·46	1			,,	,,	22·2
			85·3	1	,,	,,	25·
			84·7	1	,,	,,	35·
			84·5	1	,,	,,	37·
			84·3	1	,,	,,	41·
			83·0	1	,,	,,	62·
82·383		0			,,	,,	72·1
81·262	81·27	3	81·2	2	,,	,,	90·2
80·685		0			,,	,,	99·6
			79·8	1	,,	,,	40314·
79·255		0	79·4	1	,,	,,	23·1
			78·9	1	,,	,,	28·
			78·6	1	,,	,,	34·
78·190	78·20	1	78·2	1	,,	,,	40·1
			77·7	1	,,	,,	48·
			77·3	1	,,	,,	55·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
			2476·0	1	0·73	11·9	40376·
2475·209	2475·19	3	75·1	1	,,	,,	89·0
74·170		1	74·3	1	,,	,,	40405·7
			73·3	1	,,	,,	20·
72·709		0	72·6	2	,,	,,	29·6
			71·6	1	,,	,,	48·
70·607		0	70·7	1	,,	,,	64·0
70·143		0			0·72	,,	71·6
69·848		0			,,	,,	76·4
69·594		0	69·5	2	,,	,,	80·6
			69·0	1	,,	,,	90·
68·705		1			,,	,,	95·2
68·263		0	68·4	1	,,	,,	40502·4
	67·45	1 Pt ?	67·5	1	,,	,,	15·8
67·382	67·37	2	67·3	1	,,	,,	17·0
			66·7	1	,,	,,	28·
			66·1	1	,,	,,	38·
			65·5	1	,,	,,	48·
	65·16	1	65·0	1	,,	,,	53·4
	64·96	1			,,	,,	56·7
64·462					,,	,,	64·9
63·118	63·10	1	63·2	1	,,	,,	87·2
			62·8	1	,,	,,	92·
62·454	62·47	1	62·3	1	,,	,,	97·9
			61·8	1	,,	,,	40609·
			58·0	1	,,	12·0	71·
57·312	57·31	1			,,	,,	82·9
57·123	57·12	1	56·5	2	,,	,,	86·6
56·882					,,	,,	90·0
55·949	55·95	1			,,	,,	40705·4
55·691	55·69	2	55·5	2n	,,	,,	09·7
54·945			54·9	2	,,	,,	22·1
	54·67	1n			,,	,,	26·7
			54·5	1	,,	,,	29·
54·212	54·20	1	54·1	1	,,	,,	34·4
			53·7	1	,,	,,	43·
52·893	52·89	2	52·7	1	,,	,,	56·2
			52·5	1	,,	,,	63·
			52·2	1	,,	,,	68·
			51·7	1n	,,	,,	76·
			50·8	1	,,	,,	91·
			50·4	1	,,	,,	98·
49·916		0			,,	,,	40805·8
			49·5	1	,,	,,	13·
49·112	49·10	1n	48·8	1	,,	,,	19·1
			48·6	1	,,	,,	28·
48·316	48·30	1			,,	,,	32·4
47·850	47·84	1			,,	,,	40·3
	47·53	1			,,	,,	45·5
			47·3	1	,,	,,	49·
46·926		0			,,	,,	55·6
			45·5	1	,,	,,	79·
	45·39	1			,,	,,	81·3
45·184		1	45·2	1	,,	,,	84·7

IRIDIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
			2444·5	1	0·72	12·0	40896·
			44·1	1	,,	,,	40903·
			43·3	2	,,	12·1	16·
			42·6	1	,,	,,	28·
			41·8	1	,,	,,	41·
			41·3	1	,,	,,	50·
			40·8	1	,,	,,	58·
			40·3	2	,,	,,	67·
			39·7	1	,,	,,	77·
			39·3	1	,,	,,	83·
			37·3	1	,,	,,	41017·
2436·513	2436·50	1n			,,	,,	30·3
			36·2	1	,,	,,	35·
			35·1	1n	,,	,,	54·
			34·5	1	,,	,,	64·
34·107		0	34·1	1	,,	,,	70·7
33·433		0	33·6	1	,,	,,	82·1
			33·0	1	,,	,,	89·
	32·64	1			,,	,,	95·5
32·439	32·41	1	32·5	1	,,	,,	99·1
32·021	32·04	2			,,	,,	41105·8
31·331	31·34	2	31·3	2	,,	,,	17·6
			30·7	1	,,	,,	28·
			30·5	1	,,	,,	32·
			30·0	1	,,	,,	40·
29·830		0	29·7	1n	,,	,,	43·0
			29·0	1	,,	,,	57·
27·878		2	27·8	2	,,	12·2	76·0
27·694	27·71	2			,,	,,	79·0
27·189		0			,,	,,	87·7
26·875		0			,,	,,	93·0
26·622	26·61	1	26·5	1	,,	,,	97·4
			26·2	1	,,	,,	41205·
25·744	25·75	1	25·8	1	,,	,,	12·2
25·069	25·07	1			,,	,,	23·7
24·971	25·01	1	24·9	2	,,	,,	25·1
24·741	24·74	1	24·7	2	,,	,,	29·3
24·406	24·40	1	24·3	1	,,	,,	35·1
22·286		0			,,	,,	71·2
21·306		0			0·71	,,	87·8
			19·2	1	,,	,,	41324·
18·657		0	18·5	1	,,	,,	33·0
18·190	18·18	2	18·1	1	,,	,,	41·1
			18·0	1	,,	,,	44·
			17·3	1	,,	,,	56·
16·672		0	16·8	1	,,	,,	67·0
16·334		0			,,	,,	72·8
15·950	15·95	1	16·0	2 Rh ?	,,	,,	79·4
14·473		0			,,	,,	41405·7
			13·3	1	,,	,,	24·8
			13·2	1	,,	,,	27·
			12·8	2	,,	12·3	33·
			12·5	1n	,,	,,	38·
			11·9	1n	,,	,,	49·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
			2411·0	1	0·71	12·3	41464·
2410·818	2410·82	1			,,	,,	67·4
10·264	10·26	2			,,	,,	77·0
			10·1	2	,,	,,	80·
09·465	09·46	1	09·5	1	,,	,,	90·7
			09·1	1	,,	,,	97·
			08·5	2	,,	,,	41507·
			08·0	1	,,	,,	16·
	07·66	1			,,	,,	21·8
			07·1	1	,,	,,	31·
06·115		0			,,	,,	48·5
05·955		0	05·8″	1n	,,	,,	51·2
			05·0	1	,,	,,	68·
			03·6	1	,,	,,	92·
03·113		0	03·1	1	,,	,,	41600·4
			02·8	1	,,	,,	06·
02·379		1			,,	,,	13·1
01·866	01·86	2	01·7	1	,,	,,	22·0
			01·2	1	,,	,,	34·
			00·4	1	,,	,,	47·
			2399·2	1	,,	,,	68·
2398·824		0	98·7	6	,,	,,	74·8
			97·2	1	,,	12·4	41703·
			96·1	1	,,	,,	22·
95·974		0			,,	,,	24·3
			95·4	1	,,	,,	34·
94·404	2394·41	1n			,,	,,	51·6
			94·1	1	,,	,,	57·
			93·1	1	,,	,,	74·
			92·9	1	,,	,,	78·
91·282	91·29	3	91·2	2	,,	,,	41806·1
90·706	90·71	2	90·5	2	,,	,,	16·2
			89·7	1	,,	,,	34·
			89·4	1	,,	,,	39·
			89·0	1	,,	,,	46·
			88·6	1	,,	,,	53·
			87·8	1	,,	,,	67·
86·981	86·98	2			,,	,,	81·5
86·665	86·67	1	86·7	2	,,	,,	86·9
			86·4	2	,,	,,	92·
			84·8	6	,,	,,	41920·
83·840		0			,,	,,	36·7
			83·1	1n	,,	12·5	50·
82·270		1			,,	,,	64·3
	81·86	1	81·8	6	,,	,,	71·5
81·714	81·72	1			,,	,,	74·0
			80·9	1	,,	,,	88·
			80·3	1	,,	,,	99·
	79·45	1	79·5	1	,,	,,	14·0
			78·0	2	,,	,,	40·
			77·2	1	,,	,,	54·
			76·5	1n	,,	,,	66·
			75·8	1	,,	,,	79·
			75·6	1	,,	,,	82·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2375·195	2375·21	1	2375·2	1	0·71	12·5	41989·2
			74·8	1	,,	,,	96·
			73·8	1	0·70	,,	42114·
	73·23	1n	73·3	1n	,,	,,	24·2
72·856	72·86	3	72·8	2	,,	,,	30·8
70·462		2			,,	,,	73·4
			69·2	1	,,	,,	96·
68·486		0			,,	12·6	42208·5
68·120		4	68·2	1	,,	,,	15·0
	68·11	2	68·1	8	,,	,,	15·2
67·469		0			,,	,,	26·7
	67·12	1n			,,	,,	32·8
			66·1	1	,,	,,	51·0
65·849		1			,,	,,	55·5
			64·0	1	,,	,,	89·
63·134	63·14	2	63·2	2	,,	,,	42304·0
			62·7	1	,,	,,	12·
			61·7	1	,,	,,	31·
60·790	60·80	1	60·6	1	,,	,,	45·9
59·668		0			,,	,,	66·2
			59·4	2	,,	,,	71·
			58·8	2	,,	,,	82·
	58·25	1			,,	,,	91·7
			58·0	2	,,	,,	96·
57·623		0			,,	,,	42403·0
			57·3	1	,,	,,	09·
56·674	56·68	1	56·7	1	,,	,,	20·0
56·388		0			,,	,,	25·2
56·122		0			,,	,,	30·0
			55·9	1	,,	,,	34·
			55·5	1	,,	,,	41·
55·082	55·11	1			,,	,,	48·5
			53·1	2	,,	12·7	84·
			50·5	2	,,	,,	31·
52·705		1			,,	,,	91·6
			52·0	1	,,	,,	42504·
51·492		1	51·4	1n	,,	,,	13·5
			50·5	2	,,	,,	31·
50·136		0			,,	,,	38·0
49·790		0			,,	,,	44·3
			48·2	1	,,	,,	73·
			47·9	1	,,	,,	79·
47·329		1	47·4	1	,,	,,	88·9
			46·8	1	,,	,,	99·
			46·5	1	,,	,,	42604·
			46·2	1	,,	,,	09·
			45·3	1	,,	,,	26·
43·684	43·68	2	43·6	1	,,	,,	55·2
43·255	43·25	2	43·3	2	,,	,,	63·0
43·062		0			,,	,,	66·5
42·763		1			,,	,,	71·9
42·573		0	42·5	1	,,	,,	75·4
			41·6	2	,,	,,	93·
			40·3	1	,,	12·8	42717·

IRIDIUM—*continued.*

Arc Spectrum: Wave-length, Kayser	Arc Spectrum: Wave-length, Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length, Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
			2340·0	2	0·70	12·8	42722·
			39·2	1	,,	,,	37·
2337·628		0			,,	,,	65·6
			36·8	1	,,	,,	81·
34·575	2334·57	1	34·5	1	,,	,,	42821·6
34·406		0	34·3	1	,,	,,	24·6
33·917	33·95	1	33·8	1	,,	,,	33·3
33·372	33·37	1			,,	,,	43·7
			32·7	1	,,	,,	56·
			32·3	1	,,	,,	63·
			31·8	1	,,	,,	73·
			30·5	1	,,	,,	96·
29·469		0	29·5	2	,,	,,	42915·4
			29·0	1	,,	,,	24·
28·790		0			,,	,,	27·9
28·598		0			,,	,,	31·5
28·324		0			,,	,,	36·5
			28·1	1n	,,	,,	41·
28·046		0			,,	,,	41·7
			27·2	2	,,	12·9	57·
			26·0	1	,,	,,	79·
			25·8	1	,,	,,	83·
			25·5	1	,,	,,	89·
25·020		1			,,	,,	97·3
24·754		0			,,	,,	43002·4
24·006		0	24·1	1	,,	,,	16·2
			23·7	2	,,	,,	22·
			22·7	1	,,	,,	40·
			22·3	1	0·69	,,	48·
21·622	21·61	1	21·5	1	,,	,,	60·5
21·481	21·49	1			,,	,,	63·0
			20·0	1	,,	,,	91·
			18·3	1	,,	,,	43122·
			17·4	2	,,	,,	39·
			16·8	1	,,	,,	50·
	15·46				,,	,,	75·1
			14·9	4	,,	,,	86·
			14·1	1	,,	13·0	43200·
			12·5	1	,,	,,	30·
			12·0	1	,,	,,	40·
			11·6	1	,,	,,	47·
			10·9	1	,,	,,	60·
			10·4	1	,,	,,	70·
			10·1	1	,,	,,	75·
			09·6	1	,,	,,	84·
			09·4	1	,,	,,	88·
	09·00	1			,,	,,	95·8
			08·8	1	,,	,,	43300·
			06·7	1	,,	,,	39·
	05·54	1	05·5	1n	,,	,,	60·8
			04·6	1n	,,	,,	78·
	04·30	2			,,	,,	84·1
			04·0	1	,,	,,	90·
			01·5	1	,,	,,	43437·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
			2300·8	1	0·69	13·1	43450·
			00·5	1	,,	,,	56·
	2300·11	1			,,	,,	63·1
			2299·8	1	,,	,,	69·
			97·3	2	,,	,,	43516·
			96·3	1	,,	,,	35·
	2295·19	1	95·2	1	,,	,,	56·3
			94·5	1	,,	,,	69·
			93·7	1	,,	,,	85·
			92·5	1	,,	,,	43607·
			91·8	1	,,	,,	21·
			91·0	4	,,	,,	36·
			89·5	2	,,	,,	65·
			88·3	2	,,	13·2	87·
			87·0	2	,,	,,	43712·
			85·7	1	,,	,,	37·
			84·6	1	,,	,,	58·
			81·7	2	,,	,,	43814·
			81·2	2	,,	,,	23·
			80·6	2	,,	,,	35·
			78·5	1	,,	,,	75·
			77·7	1	0·68	,,	91·
			77·3	1	,,	,,	98·
			77·1	1	,,	,,	43902·
			76·3	1	,,	,,	18·
			75·6	1	,,	13·3	31·
			72·5	1n	,,	,,	91·
			71·4	2	,,	,,	44012·
			68·9	2	,,	,,	61·
			68·5	2	,,	,,	69·
			68·1	1	,,	,,	76·
			67·8	1	,,	,,	82·
			65·3	2	,,	,,	44131·
	64·73	1	64·7	1n	,,	,,	42·1
			63·0	1n	,,	13·4	76·
			62·4	1n	,,	,,	87·
			62·2	1	,,	,,	91·
			59·3	2	,,	,,	44248·
	59·00	1			,,	,,	54·0
			58·8	1	,,	,,	58·
			58·4	2	,,	,,	66·
			57·5	2	,,	,,	83·
			57·1	2	,,	,,	91·
			56·5	1	,,	,,	44303·
			56·0	1	,,	,,	13·
			55·5	1	,,	,,	23·
	55·22	1	55·3	1	,,	,,	28·2
	53·60	1n			,,	,,	60·0
			53·3	1	,,	,,	66·
			52·0	1	,,	,,	92·
			51·5	1	,,	,,	44401·
			50·7	1	,,	13·5	17·
			49·4	1	,,	,,	43·
			48·8	1	,,	,,	55·

IRIDIUM—*continued.*

Arc Spectrum			Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
			2247·7	1	0·68	13·5	44476·
			46·7	2	,,	,,	96·
			45·5	2	,,	,,	44520·
			43·8	1	,,	,,	54·
	2242·80	2	42·6	4	,,	,,	73·6
			40·5	1	,,	,,	44610·
			38·7	1	,,	13·6	55·
			38·3	2	,,	,,	63·
			38·1	1	,,	,,	67·
			37·1	2	,,	,,	87·
			36·3	1	,,	,,	44703·
			34·3	1	,,	,,	43·
			34·0	1	,,	,,	49·
			33·2	1	,,	,,	65·
			32·0	1	,,	,,	89·
			24·2	1	0·67	13·7	44946·
			20·6	1n	,,	,,	45019·
			19·3	1	,,	,,	46·
			18·9	1	,,	,,	54·
			12·4	1	,,	13·8	45186·
			11·2	1	,,	,,	45211·
			10·2	1n	,,	,,	31·
			08·7	1n	,,	,,	62·
			05·0	2	,,	,,	45338·
			2197·5	1	,,	13·9	45492·
			96·1	1	,,	,,	45521·
			92·2	1	,,	14·0	45602·
			90·3	2	,,	,,	42·
			87·0	1	,,	,,	45711·
			78·5	1	0·66	14·1	45889·
			69·3	1	,,	14·2	46184·
			52·6	1	,,	14·3	46441·
			51·7	1	,,	,,	61·

Osmium.

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Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5728·735			2			1·56	4·7	17451·2
5523·786			2			1·51	4·9	18098·6
02·789			3			1·50	5·0	67·6
5149·895			2			1·41	5·3	19412·7
03·670			2			1·40	5·4	19588·3
5031·988			1			1·38	,,	19867·5
4937·522			0			1·35	5·6	20248·1
12·771			1			1·34	,,	20349·5
4899·386			0			,,	,,	20405·1
65·759			2			1·33	,,	20546·2
16·105			2			1·32	5·7	20758·0
4794·177			5			1·31	,,	20852·9
63·263			0			1·30	5·8	20983·8
55·332			1			,,	,,	21023·2
44·050			2			,,	,,	73·2
38·508			2			,,	,,	97·9
38·215			1			,,	,,	99·2
				4696·8	1n	1·29	5·9	21285·
4692·220		4692·20	2	92·2	1n	1·28	,,	21306·0
				70·6	1n	,,	,,	21405·
				67·5	1n	,,	,,	419·
				64·1	1	,,	,,	434·
63·977		63·99	3			,,	,,	435·0
42·010			0			1·27	,,	21536·5
34·930		34·94	1n			,,	6·0	569·3
32·000		32·01	4	32·0	1	,,	,,	582·9
16·948	4616·944	16·94	3	16·9	1	1·26	,,	21653·3
4597·321		4597·35	2	4597·3	1n	,,	,,	21745·7
95·206		95·22	1n	95·2	1n	,,	,,	755·8
				88·1	1	,,	,,	790·
				79·3	1	1·25	,,	21831·
				72·9	1	,,	,,	862·
				66·6	1	,,	,,	892·
				57·7	1n	,,	6·1	21935·
				56·9	1	,,	,,	939·
51·461	4551·463	51·50	4	51·5	2	,,	,,	964·8
50·584	50·571	50·59	8	50·58	8	,,	,,	969·1
48·836	48·827	48·85	3	48·8	1	,,	,,	977·5
				46·2	1n	,,	,,	990·
				45·2	1	,,	,,	995·
40·093	40·087	40·10	2	40·1	1	1·24	,,	22019·9
				37·8	1	,,	,,	031·
29·848	29·842	29·88	1	29·9	1	,,	,,	069·7
25·035	25·035	25·03	1	25·1	1	,,	,,	093·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
				4523·5	1b	1·24	6·1	22101·
				20·06	10	,,	,,	14·6
				20·5	1	,,	,,	15·
				20·2	1	,,	,,	17·
4519·050			0	19·1	1	,,	,,	22·4
14·445			0			,,	,,	45·0
				11·0	1b	,,	,,	62·
07·590			0			,,	,,	78·7
03·474			0			1·23	,,	99·0
				01·1	1	,,	,,	22211·
				4490·3	1n	,,	6·2	64·
4488·771	4488·766	4488·75	1	88·7	1	,,	,,	71·7
84·935	84·930	84·94	3	84·9	2	,,	,,	90·7
				84·3	1	,,	,,	94·
79·974	79·976	79·98	2	80·0	1	,,	,,	22315·4
66·134	66·121		1	66·2	1n	1·22	,,	84·6
62·473	62·470		1	62·5	1	,,	,,	22402·9
59·790	59·781	59·80	1			,,	,,	16·4
59·646	59·658	59·68	1	59·7	2	,,	,,	17·0
				58·5	1	,,	,,	23·
47·535	47·520	47·52	4	47·5	2	,,	,,	78·3
45·854	45·850		1	45·8	1	,,	,,	86·7
45·582			1			,,	,,	88·0
39·808	39·810	39·80	2	39·8	1	,,	,,	22517·3
37·258	37·257	37·26	1	37·3	1	,,	,,	30·2
36·490	36·488	36·48	5	36·5	2	,,	,,	34·2
				36·0	1	,,	,,	37·
32·584	32·582	32·59	3	32·6	2	,,	,,	54·0
28·059			1			,,	6·3	77·0
				24·7	1b	1·21	,,	94·
				23·7	1	,,	,,	99·
20·639	20·633	20·64	12	20·66	10	,,	,,	22614·9
11·298		11·30	1			,,	,,	62·8
10·899			1	05·0	1	,,	,,	64·8
04·375	04·378	04·40	2	04·3	1	,,	,,	98·3
02·901	02·904	02·92	3			,,	,,	22706·0
00·751	00·747	00·75	2	00·7	1n	,,	,,	17·1
4397·424	4397·427	4397·45	4	4397·5	2	,,	,,	34·2
95·040	95·042	95·05	8	95·08	8	,,	,,	46·6
91·251	91·242	91·30	2	91·3	2	1·20	,,	66·2
90·406			0			,,	,,	70·6
				90·0	1n	,,	,,	73·
86·485			1	86·5	1	,,	6·4	90·9
85·068			0	85·1	1n	,,	,,	98·3
77·070	77·068	77·05	1n	77·0	1	,,	,,	22840·0
70·826	70·824	70·84	3	70·8	2	,,	,,	72·6
65·835	65·837	65·85	5	65·83	4	,,	,,	98·7
61·126			0	61·2	1n	,,	,,	22923·5
58·318	58·304	58·31	1	58·3″	2n	,,	,,	22938·3
58·157	58·153	58·16	1			,,	,,	39·1
				56·6	1	1·19	,,	47·
54·631	54·626	54·64	1	54·6	1	,,	,,	57·6
				53·7	1	,,	,,	63·
51·695	51·691	51·72	3			,,	,,	73·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		4345·75	1			1·19	6·4	23000·
		44·83	1			,,	,,	09·
4342·681	4342·678	42·70	2			,,	,,	20·8
38·913	38·919	38·91	3	4338·9	2	,,	,,	40·8
		33·11	1			,,	,,	71·7
28·838	28·840	28·85	5	28·83	6	,,	,,	94·5
26·413	26·416	26·41	4	26·4	2	,,	,,	23107·4
				22·9	1	,,	,,	26·
19·513	19·502	19·50	2			,,	,,	44·4
		18·15	1n			1·18	,,	51·7
17·754	17·743	17·73	1			,,	,,	53·8
				12·4	1	,,	,,	83·
11·561	11·560	11·57	7	11·55	8	,,	,,	87·0
09·041	09·041	09·05	3	09·1	1	,,	,,	23200·6
				07·9	1	,,	6·5	07·
	05·440	05·45	1	05·5	1	,,	,,	19·9
				00·0″	1	,,	,,	49·
4299·870	4299·856	4299·87	1			,,	,,	50·1
				4298·6	1n	,,	,,	57·
97·556	97·538	97·56	1	97·6	1n	,,	,,	62·6
96·381	96·383	96·40	3	96·4	1	,,	,,	68·9
94·105	94·113	94·14	10	94·05	10	,,	,,	81·2
		93·10	1	93·1	1n	,,	,,	86·7
				92·0	1n	,,	,,	93·
		88·13	1			,,	,,	23313·7
86·056	86·056	86·05	3	86·1	2	,,	,,	25·0
		84·44	1	84:6	1n	,,	,,	33·8
81·535	81·520	81·54	1	81·5	1	,,	,,	49·6
77·315	77·302	77·30	2	77·4	1	1·17	,,	72·7
75·074	75·064	75·10	2n	75·2	1	,,	,,	84·9
73·984						,,	,,	90·9
				72·0	1	,,	,,	23402·
70·952	70·945	70·95	2	71·0	1	,,	,,	07·5
				69·9	1	,,	,,	13·
69·767	69·767	69·78	3	69·7	1	,,	,,	13·9
69·526	69·521	69·53	2			,,	,,	15·3
64·893	64·903	64·91	3	65·0	2	,,	,,	40·7
				64·6	1	,,	,,	42·
61·011	60·993	61·01	15	60·98	10	,,	,,	62·1
52·718	52·690	52·73	2	52·7	1	,,	6·6	23507·8
51·321	51·331	51·40	2	51·4	1n	,,	,,	15·3
		47·69	1n			,,	,,	35·6
		43·32	1n			1·16	,,	59·9
41·682	41·679	41·70	2			,,	,,	68·9
		37·31	1	33·6	2	,,	,,	93·3
33·630	33·613	33·65	4			,,	,,	23613·8
		32·20	1			,,	,,	21·8
29·531		29·51	1			,,	,,	36·7
	26·675	26·72	2			,,	,,	52·5
		19·84	1	19·9	1n	,,	,,	91·0
19·005	18·991	19·02	1	19·0	1n	,,	,,	95·7
		15·33	3	15·4	1	,,	,,	23716·3
		14·06	4	14·0	2	,,	,,	23·5
12·028	12·007	12·06	15	12·02	10	,,	,,	34·9

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				4208·1	1n	1·16	6·6	23757·
		4205·40	2	05·4	1n	1·15	,,	72·3
		04·76	2	04·8	1n	,,	,,	76·0
		02·25	5			,,	,,	90·2
4201·541	4201·528	01·59	4	01·5	2	,,	,,	94·1
		4195·31	2	4195·4	1	,,	6·7	23829·4
		94·37	1	94·5	1	,,	,,	34·8
		93·06	1	93·0	1n	,,	,,	42·2
		92·80	2			,,	,,	43·7
		92·35	2	92·5	1	,,	,,	46·3
4190·059	4190·052	90·07	5	90·1	2	,,	,,	59·3
		86·50	1			,,	,,	79·6
		85·18	1			,,	,,	87·1
		84·30	3	84·4	2	,,	,,	92·2
		82·64	2	82·6	1n	,,	,,	23901·6
				80·4	1n	,,	,,	14·
75·783	75·781	75·78	6	75·78	8	,,	,,	40·9
		74·77	1	75·0	1	,,	,,	46·7
73·391	73·386	73·40	8	73·35	8	,,	,,	54·6
72·708	72·710	72·71	8	72·7	2	,,	,,	58·6
		70·97	1			,,	,,	68·5
				66·5	1	1·14	,,	94·
				66·0	1	,,	,,	97·
				65·0	1	,,	,,	24003·
		61·09	1	61·1	1	,,	,,	25·5
		60·45	2n	60·5	1	,,	,,	29·2
		60·15	2	60·2	1	,,	,,	30·9
	58·948	58·98	3	59·0	2	,,	,,	37·7
		53·80	1			,,	,,	67·6
		53·53	2			,,	,,	69·2
		52·79	1			,,	,,	73·5
52·448	52·455		5			,,	,,	75·5
		50·90	2	51·0	1	,,	,,	84·5
				48·4	1	,,	,,	99·0
		47·50	2	47·5	1	,,	6·8	24104·1
		44·74	1			,,	,,	20·2
		43·33	1	38·9	1	,,	,,	28·4
38·021	38·013	38·00	4	38·0	2	,,	,,	59·4
35·955	35·945	35·96	10	35·93	10	,,	,,	71·4
		35·20	2	35·0	1	,,	,,	75·8
				32·3	1b	,,	,,	93·
		31·20	2	31·2	1b	,,	,,	99·2
29·114	29·124	29·12	3	29·2	2	1·13	,,	24211·4
				29·1	1 Rh ?	,,	,,	12·
		27·45	1	27·5	1	,,	,,	21·2
		26·26	1	26·2	1	,,	,,	28·2
		25·44	1	25·5	1	,,	,,	33·0
24·760	24·762	24·76	3	24·8	2	,,	,,	37·0
		16·71	1n			,,	,,	84·4
		16·40	1n	15·0	1b	,,	,,	86·3
12·177	12·185	12·19	12	12·12	8	,,	,,	24311·2
		11·19	2			,,	,,	17·1
		09·22	1	09·3	1n	,,	,,	28·7
		08·14	2	08·0	1n	,,	,,	35·1

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				4106·3	1	1·13	6·8	24346·
		4105·60	2			,,	,,	50·2
		03·80	3	00·5	2	,,	,,	60·9
4100·436	4100·446	00·46	3			,,	,,	80·8
4098·233	4098·264	4098·29	3	4098·3	1	,,	6·9	93·7
97·087	97·090		2			,,	,,	24400·8
	97·004		2			,,	,,	00·8
		96·26	1			,,	,,	05·6
91·980	91·977	91·99	6	91·98	4	1·12	,,	31·1
		91·18	1n			,,	,,	35·9
	90·922	90·99	1n	91·0	1	,,	,,	37·3
88·598	88·593	88·58	3	88·6	1	,,	,,	51·4
				84·8	1n	,,	,,	84·
		76·85	1			,,	,,	24521·8
		75·02	1			,,	,,	32·9
74·829	74·834	74·83	4	74·9	2	,,	,,	34·0
73·768	73·763	73·78	4	73·8	1	,,	,,	40·4
	71·716	71·71	3	71·7	1	,,	,,	52·8
71·169	71·162	71·15	2n	71·2	2	,,	,,	56·1
71·020	71·008	71·01	4			,,	,,	57·0
66·862	66·848	66·85	10	66·82	10	,,	,,	82·1
66·460	66·464	66·47	2			,,	,,	84·5
			1	62·8	1n	,,	,,	24607·
		61·78				,,	,,	12·8
		60·85	1	60·9	1	,,	,,	18·5
		56·49	1n			,,	,,	44·9
55·859			0			,,	,,	48·8
55·646	55·641	55·65	2	55·6	1	,,	,,	50·1
		53·96	1n	53·9	1	1·11	,,	60·3
53·417	53·407	53·40	1	53·4	1	,,	,,	63·7
51·584	51·580	51·59	2	51·6	1	,,	,,	84·8
		50·72	1	50·7	1	,,	7·0	80·0
				50·3	1	,,	,,	83·
48·216	48·197	48·20	3	48·3	1	,,	,,	95·3
		42·95	1			,,	,,	24727·4
42·081	42·073	42·09	4	42·1	2	,,	,,	33·2
				39·6	1	,,	,,	48·
38·813			0			,,	,,	52·7
38·809		38·80	1	38·8	1	,,	,,	52·8
	38·782		2			,,	,,	52·9
	38·017	38·00	2	37·9	1	,,	,,	57·7
36·640	36·634	36·61	1	36·6	1	,,	,,	66·1
35·249	35·250	35·26	1	35·3	1	,,	,,	74·6
	33·095	33·12	1 Ga ?	33·0	1	,,	,,	87·8
				30·8	1n	,,	,,	24802·
				29·7	1n	,,	,,	09·
				24·0	1n	,,	,,	44·
				22·9	1n	,,	,,	51·
		20·56	1	20·6	1n	,,	,,	65·2
18·425	18·430	18·38	4	18·4	2	,,	,,	78·5
15·203	15·211	15·18	2	15·2	1	1·10	,,	98·4
				15·1	1	,,	,,	99·
		12·60	1 Ti ?	12·6	1b	,,	,,	24914·
		11·14	1	11·0	1	,,	,,	23·6

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
	4005·327	4005·29	5			1·10	7·0	24959·9
4004·184	04·193	04·18	3	4004·2	2	,,	,,	66·9
03·652	03·652	03·64	4	03·6	2	,,	7·1	70·1
		01·50	1	01·4	1b	,,	,,	83·5
3999·110	3999·103	3999·10	2	3999·2	1	,,	,,	98·5
				98·2	1n	,,	,,	25004·
96·979	96·972	96·99	2			,,	,,	11·8
95·103	95·096	95·10	2			,,	,,	12·3
	91·640	91·66	2			,,	,,	32·9
88·785	88·783	88·76	1			,,	,,	63·2
88·340	88·343	88·32	2	88·3	1	,,	,,	66·0
				85·6	1	,,	,,	83·2
79·524	79·521	79·53	1	79·5	1n	,,	,,	25121·5
77·389	77·391	77·39	10	77·33	4	,,	,,	35·0
75·596	75·598	75·59	3	75·5	1	1·09	,,	46·4
		74·00	1			,,	,,	56·5
				71·5	1	,,	,,	72·
				71·6	1	,,	,,	72·
69·832	69·835	69·82	4	69·8	1	,,	,,	83·1
				66·6	1	,,	,,	25203·
65·106	65·112	65·08	3	65·1	1	,,	,,	12·9
63·774	63·777	63·80	10	63·80	6	,,	,,	21·3
		63·48	1			,,	,,	23·3
61·159	61·163			61·2	2	,,	,,	38·0
60·656	60·653	60·65	3	60·6	1	,,	,,	41·3
				58·0	1	,,	,,	58·
		57·80	1n			,,	,,	59·5
		55·53	2			,,	7·2	73·9
		54·72	1n			,,	,,	79·0
				53·5	1	,,	,,	87·
52·904	52·911	52·91	2	53·0	1	,,	,,	90·6
49·925	49·921	49·93	3	49·9	1	,,	,,	25309·7
				49·3	1n	,,	,,	14·
		40·20	1			,,	,,	72·2
39·704	39·708	39·71	3	39·7	1	,,	,,	75·4
38·739	38·739	38·74	1	38·7	2	,,	,,	81·6
				36·6	1	1·08	,,	95·
		35·67	1	35·7	1b	,,	,,	25401·4
31·660	31·660	31·70	2	31·7	1	,,	,,	27·3
30·148	30·138	30·14	4	30·1	1	,,	,,	37·2
28·691	28·681	28·68	3	28·6	1n	,,	,,	46·6
28·557	28·554	28·57	2			,,	,,	47·4
		28·31	1			,,	,,	49·0
		27·40	1			,,	,,	54·9
26·923	26·916	26·93	2	26·9	1	,,	,,	58·0
25·253	25·244	25·25	2	25·2	1	,,	,,	68·9
		22·15	2	22·2	1	,,	,,	89·0
		21·00	2	21·0	1	,,	,,	96·5
	19·107	19·09	1			,,	,,	25508·9
	18·888	18·85	2			,,	,,	10·4
15·543			0			,,	,,	32·0
		11·95	2			,,	,,	55·5
				10·7	1	,,	,,	64·
		07·78	1			,,	7·3	82·7

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3906·28	1	3906·2	1b	1·08	7·3	25592·5
		05·65	1 Si ?			,,	,,	96·6
				05·2	1b	,,	,,	25600·
				03·2	1b	,,	,,	13·
				02·0	1b	,,	,,	21·
3901·851	3901·843	01·87	5	01·8	2	,,	,,	21·5
		01·16″	2	01·1	1	,,	,,	26·1
00·541	00·527	00·54	4	00·5	1	,,	,,	30·2
		3899·18	1			,,	,,	39·1
		97·30	1			,,	,,	51·5
3895·331	3895·305	95·34	2	3895·3	1	1·07	,,	64·5
	95·023	95·05	1	95·0	2	,,	,,	66·4
		94·83	1			,,	,,	67·8
		93·40	1n	92·1	1b	,,	,,	77·2
		92·99	1			,,	,,	79·9
		91·75	1			,,	,,	88·1
		88·97	1			,,	,,	25706·5
		86·91	2	86·9	1	,,	,,	20·1
		85·90	2	85·9	1	,,	,,	26·8
		84·75	1			,,	,,	34·4
				83·5	1n	,,	,,	43·
		82·02	4	82·0	2	,,	,,	52·5
		80·93	2	80·9	1	,,	,,	59·7
		78·65	3			,,	,,	74·9
		78·05	3			,,	,,	78·9
		77·45	2	77·5	1	,,	,,	82·8
	76·971	76·91	8	76·95	4	,,	,,	86·2
		75·82	1n			,,	,,	93·7
		75·26	1			,,	,,	97·4
				74·2	1n	,,	,,	25804·
		73·86	2	73·8	1n	,,	,,	06·7
		73·17	1			,,	,,	11·3
				71·1	1	,,	,,	25·
		69·15	1			,,	,,	38·2
		68·83	2	68·8	1	,,	,,	40·3
		66·65	2			,,	,,	54·9
		66·19	1			,,	,,	58·0
		65·59	6			,,	,,	62·0
		65·19	2			,,	,,	64·7
				62·7	1b	,,	,,	81·
		60·95	1			,,	,,	93·1
				59·8	1	,,	,,	25901·
		57·24	10	57·2	2	,,	,,	18·0
		54·86	2	54·8	1	1·06	,,	34·0
		53·75	2n			,,	,,	41·4
		53·60	3	53·6	1	,,	,,	42·5
		50·11	10			,,	,,	66·0
		48·94	1	49·0	1	,,	,,	73·9
		47·71	1			,,	,,	82·2
				47·4	1	,,	,,	84·
		47·01	1			,,	,,	86·9
		46·55	2	46·6	1n	,,	,,	90·0
		45·81	1			,,	,,	95·0
		44·95	1			,,	,,	26000·8

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3843·77	3	3843·7	1	1·06	7·3	26008·8
		42·40	1			,,	,,	18·1
		41·80	1			,,	,,	22·2
		41·41	5	41·4	2	,,	,,	24·8
		40·44	10	40·4	2	,,	,,	31·4
		36·18	10	36·2	2	,,	,,	60·3
				32·5	1	,,	,,	85·
		32·33	2	32·3	1 Pd ?	,,	,,	86·5
		31·55	1			,,	,,	91·8
		30·26	1			,,	,,	26100·6
		29·20	1			,,	,,	07·8
		27·30	3	27·2	1	,,	,,	20·8
		26·78	2	26·7	1	,,	,,	24·3
				26·5	1	,,	,,	26·2
		23·47	1			,,	,,	47·0
		22·06	2	22·1	1n	,,	,,	56·6
		21·80	2	21·8	1n	,,	,,	58·4
		18·80	2 Pt ?			,,	,,	78·9
				18·7	1	,,	,,	80·
		18·21	2			,,	7·4	82·9
				18·0	1b	,,	,,	84·
		17·78	2			,,	,,	85·8
		14·42	2	14·4	1	1·05	,,	26208·9
		14·20	1			,,	,,	10·4
		12·45	2	12·4	1	,,	,,	22·5
				11·1	1	,,	,,	32·
		10·59	1	10·6	1	,,	,,	35·3
		09·80	1	09·7	1	,,	,,	40·7
				07·8	1	,,	,,	54·
		04·27	1			,,	,,	78·9
		02·77	2	02·7	1	,,	,,	89·2
		01·75	2	01·7	1	,,	,,	96·3
		01·40	1n			,,	,,	98·7
		01·23	1			,,	,,	99·9
		00·90	1			,,	,,	26302·2
		00·58	3	00·6	1	,,	,,	04·4
		00·06	1			,,	,,	08·0
		3797·86	1			,,	,,	23·2
		95·83	3	3795·8	1	,,	,,	37·3
				95·2	1	,,	,,	42·
		94·84	3	94·9	1	,,	,,	44·2
	3794·054	94·08	10	94·1	4	,,	,,	49·5
				94·02	4	,,	,,	49·9
		92·18	1			,,	,,	62·7
		91·23	1			,,	,,	69·3
		90·90	4	90·9	2	,,	,,	71·6
	90·244	90·29	6	90·26	4	,,	,,	76·0
		89·25	3	89·2	1	,,	,,	83·0
		89·04	1			,,	,,	84·5
		86·14	1 Ti ?	86·1	1	,,	,,	26404·7
		85·88	1	85·8	1n	,,	,,	06·5
		85·82	1			,,	,,	07·0
				84·6	1	,,	,,	15·
				84·3	1	,,	,,	18·

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
		3783·82	2	3783·8	1	1·05	7·4	26420·9
		82·90	1			,,	,,	27·4
		82·34	20	82·34	8	,,	,,	31·3
		81·99	1n			,,	,,	33·7
		80·74	1	80·7	1	,,	,,	42·5
		80·37	2	80·3	1	,,	,,	45·0
				79·6	1	,,	,,	50·
		77·13	5	77·1	1	,,	,,	67·7
		76·40	3	76·4	1	1·04	,,	72·8
		76·16	1	76·2	1	,,	,,	74·5
		76·10	1			,,	,,	75·0
		74·77	3	74·7	1	,,	,,	84·3
		74·55	3	74·5	1	,,	,,	85·8
		74·30	1			,,	,,	87·6
		73·95	2			,,	,,	90·0
		72·09	2	72·0	1	,,	7·5	26503·0
		71·78	2	71·7	1	,,	,,	05·2
	3771·040	71·00	2	71·1	1b	,,	,,	10·7
		70·48	1			,,	,,	14·3
		69·44	1			,,	,,	21·6
		68·27	4	68·3	1	,,	,,	29·9
		66·43	4	66·4	1	,,	,,	42·8
		64·83	1	64·8	1n	,,	,,	54·1
				64·1	1	,,	,,	59·
				60·9	1	,,	,,	82·
		60·40	2	60·4	1	,,	,,	85·4
		58·25	1			,,	,,	26600·6
		57·21	3	57·2	1	,,	,,	08·0
		56·91	1			,,	,,	10·1
				56·8	1	,,	,,	11·
		56·70	1			,,	,,	11·6
		54·65	1n	54·6	2	,,	,,	26·1
		53·99	1			,,	,,	30·8
		52·69″	20	52·68	10	,,	,,	40·1
		52·06	2	52·1	1	,,	,,	44·5
				51·9	1	,,	,,	46·
		51·45	2	51·4	1	,,	,,	48·8
		50·95	2			,,	,,	52·4
		50·72	2			,,	,,	54·0
		49·99	1			,,	,,	59·2
		49·18	2			,,	,,	65·0
				48·4	1	,,	,,	71·
		47·18	1			,,	,,	79·2
3746·612		46·60	4	46·5	2	,,	,,	83·3
		44·52	1			,,	,,	98·2
		44·00	1			,,	,,	26701·9
		43·80	1			,,	,,	03·3
		41·66	2	41·7	1n	,,	,,	18·6
		41·22	2	41·2	1	,,	,,	21·7
		40·39	1			,,	,,	27·7
		40·20	1			,,	,,	29·0
				37·1	1	1·03	,,	51·
		35·66	2	35·6″	1	,,	,,	61·5
		35·36	1			,,	,,	63·7

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3734·70	1			1·03	7·5	26768·4
		33·50	1			,,	,,	77·0
		32·99	1	3732·9	1n	,,	,,	80·7
		31·95	2	31·9	1	,,	,,	88·1
		30·88	3	30·9	1	,,	,,	95·8
		29·37	3			,,	,,	26806·7
		28·85	1			,,	,,	10·4
		28·52	2	28·5	1	,,	,,	12·8
		26·13	1			,,	7·6	29·9
		25·45	2	25·4	1	,,	,,	34·8
		22·11	2	22·1	1	,,	,,	58·9
		20·27	10	20·3	2	,,	,,	72·2
				20·1	2	,,	,,	73·
		19·64	10	19·6	2	,,	,,	76·7
		18·87	1			,,	,,	82·3
		18·49	3	18·5	1	,,	,,	85·0
		18·06	2	18·1	1	,,	,,	88·1
		17·54	1			,,	,,	91·9
		17·00	1			,,	,,	95·8
		16·48	2			,,	,,	99·6
		16·38	3	16·4	1n	,,	,,	26900·2
				15·2	1b	,,	,,	09·
		14·13	2n			,,	,,	16·6
		13·88	4	13·9	2	,,	,,	18·4
		12·99	2			,,	,,	24·9
		12·60	2			,,	,,	27·7
				11·9	1	,,	,,	32·8
		09·30	5			,,	,,	51·7
		06·72	4	06·6	2	,,	,,	70·4
				04·2	1	,,	,,	89·
3703·391		03·40	4	03·4	2	,,	,,	94·6
		02·95	2			,,	,,	97·9
		01·75	2			,,	,,	27006·6
				01·6	1	,,	,,	08·
		01·45	1	01·4	1	,,	,,	08·8
00·688			1			,,	,,	14·4
		00·45	2	00·4	1	,,	,,	16·1
		3698·98	2	3698·9	1	,,	,,	26·9
				95·9	1n	1·02	,,	49·
		95·80	1			,,	,,	50·1
		95·35	1	95·4	1n	,,	,,	53·4
		94·53	1			,,	,,	59·4
				94·4	1n	,,	,,	60·
				93·8	1n	,,	,,	65·
		93·15	1			,,	,,	69·5
		92·80	1	92·75	4	,,	,,	72·1
		92·41	1			,,	,,	75·0
3691·750			0			,,	,,	79·8
		90·88	2			,,	,,	86·2
				89·5	1	,,	,,	96·
89·191		89·21	5	89·1	2	,,	,,	98·5
		88·05	1			,,	,,	27107·0
		87·40	1			,,	,,	11·8
		87·19	1	87·1	1	,,	,,	13·3

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3686·2	1	1·02	7·6	27121·
		3685·55	1			,,	,,	25·4
		84·70	2			,,	,,	31·6
				84·5	1	,,	,,	33·
		84·00	1	84·2	1	,,	,,	36·8
3681·705		81·74	3	81·7	1	,,	7·7	53·5
		78·40	1			,,	,,	78·0
		78·15	2	78·2	1	,,	,,	79·9
75·599		75·60	4	75·5	1	,,	,,	98·7
		74·67	1			,,	,,	27205·6
				73·3	1b	,,	,,	16·
		73·01	1			,,	,,	17·9
				72·1	1	,,	,,	25·
		71·60	1			,,	,,	28·4
71·040	3671·040	71·05	6	71·1	2	,,	,,	32·5
		69·85	1			,,	,,	41·4
		69·63	1			,,	,,	43·0
		69·25	1			,,	,,	45·8
		68·34	1	68·4	2	,,	,,	52·6
		66·48	4	66·4	2	,,	,,	66·4
				65·1	2	,,	,,	77·
		61·40	2	61·4	1	,,	,,	27304·3
		60·92	1			1·01	,,	07·8
				59·8	1n	,,	,,	16·
		57·57	1			,,	,,	32·9
57·048	57·053	57·05	6	57·1	2	,,	,,	36·7
		56·55	1			,,	,,	40·5
		54·95	1			,,	,,	52·5
54·631	54·639	54·64	5	54·6	2	,,	,,	54·8
53·873		53·86	3	53·9	1	,,	,,	60·6
		53·35	2			,,	,,	64·4
		50·52	2			,,	,,	85·7
				50·4	1	,,	,,	87·
48·962		48·94	3	48·9	1	,,	,,	97·4
		48·45	2	48·4	1	,,	,,	27401·2
		45·28	1			,,	,,	25·0
		42·65	2			,,	,,	44·8
				42·6	1	,,	,,	
				42·3	1	,,	,,	47·
		41·40	2	41·4	1	,,	,,	54·3
				40·8	2	,,	,,	59·
40·487	40·484	40·50	8	40·48	4	,,	,,	61·1
				39·73	8	,,	,,	66·9
		39·44	1			,,	,,	74·4
		38·72	1			,,	7·8	78·3
		38·20	1	38·1	1b	,,	,,	79·
		35·40	1n			,,	,,	99·5
				32·2	1n	,,	,,	27524·
		31·95	1			,,	,,	25·6
		30·95	1			,,	,,	33·2
		30·56	1			,,	,,	36·2
30·099		30·12	3	30·1	1	,,	,,	39·6
		27·39	1			,,	,,	60·2
		26·05	1			,,	,,	70·4

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3625·53	1			1·01	7·8	27574·4
				3621·7	1	,,	,,	27604·
		21·26	1	21·2	1	,,	,,	06·9
		20·40	2	20·4	1	,,	,,	13·5
		19·59	3	19·5	1	,,	,,	19·6
				17·1	1	1·00	,,	39·
3616·726		16·73	8	16·7	2	,,	,,	41·5
		15·77	1			,,	,,	48·8
		13·50	3	13·4	1	,,	,,	66·2
				12·9	1	,,	,,	71·
				12·4	1	,,	,,	75·
				10·5	1n	,,	,,	89·
		09·83	1			,,	,,	94·3
		09·30	3	09·3	1	,,	,,	98·4
				09·0	1	,,	,,	27701·
		07·54	1			,,	,,	11·9
		05·97	1			,,	,,	24·0
04·624		04·65	2	04·62	4	,,	,,	34·2
		04·50	1n			,,	,,	35·3
		04·02	1			,,	,,	39·0
				03·9	1	,,	,,	40·
				03·2	1	,,	,,	45·
		02·99	1			,,	,,	46·9
		02·64	2	02·5	1	,,	,,	49·6
01·984		02·00	4	02·0	1	,,	,,	54·5
3598·266	3598·264	3598·25	10	3598·2	2	,,	,,	83·4
		97·66	2	97·6	1	,,	,,	88·1
		95·96	1			,,	,,	27801·2
				93·8	1n	,,	7·9	18·
				93·0	1n	,,	,,	24·
		92·49	3	92·4	1	,,	,,	27·9
		91·77	1			,,	,,	33·5
				91·6	1	,,	,,	35·
				91·3	1	,,	,,	37·
		90·28	3	90·2	1	,,	,,	45·1
		89·48	1			,,	,,	51·3
		88·11	1			,,	,,	61·9
		87·48	4	87·4	2	,,	,,	66·8
		86·65	3			,,	,,	73·3
				86·5	1	,,	,,	74·
		84·56	2	84·5	2	,,	,,	89·5
		83·55	2	83·4	1	,,	,,	97·4
		83·21	2	83·2	1	,,	,,	27900·0
		82·95	1	82·9	1	,,	,,	02·1
				82·3	1	,,	,,	07·
				82·2	1	,,	,,	08·
		80·68	1			,,	,,	25·0
		80·01	1	77·8	1	,,	,,	42·
		77·65	1			0·99	,,	43·4
				74·9	1	,,	,,	65·
		74·25	3	74·2	1	,,	,,	70·0
		72·93	1			,,	,,	80·3
				72·6	1n	,,	,,	83·
		71·70	1			,,	,,	90·0

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3569·94	4	3569·9	2	0·99	7·9	28003·8
		69·17	1	69·2	1n	,,	,,	09·8
		68·75	1			,,	,,	13·1
		67·23	1			,,	,,	25·1
				65·3	1	,,	,,	40·
		64·25	2	64·2	1n	,,	,,	48·5
				63·4	1n	,,	,,	55·
				63·1	1n	,,	,,	58·
		62·51	4	62·4	1	,,	,,	62·2
		61·55	1			,,	,,	69·8
		61·03	10	61·08	8	,,	,,	73·9
		60·61	1			,,	,,	77·2
				60·02	6	,,	,,	81·8
		59·97	10	59·8	6	,,	,,	82·2
		58·96	1			,,	,,	90·2
		58·10	1			,,	,,	97·0
				57·4	1n	,,	,,	28103·
		56·11	2			,,	,,	12·7
		55·85	2			,,	,,	14·8
		54·70	1			,,	,,	23·9
		54·20	1	54·1	1	,,	,,	27·8
		51·09	1	51·0	1	,,	,,	52·4
		50·86	1	50·8	1	,,	8·0	54·2
		49·81	1			,,	,,	62·5
		49·65	2			,,	,,	63·8
		49·17	1			,,	,,	67·6
				49·0	1n	,,	,,	69·
		48·87	1			,,	,,	70·0
		48·03	1			,,	,,	76·6
				47·7	1	,,	,,	79·
		46·25	1	46·1	1n	,,	,,	90·8
				45·6	1n	,,	,,	96·
		44·70	2	44·6	1	,,	,,	28203·1
		43·85	2	43·7	1	,,	,,	09·9
		43·43	1	43·3	1	,,	,,	13·2
		42·85	5	42·6	2	,,	,,	17·9
		42·03	2	42·0	1	,,	,,	24·4
		41·68	1			,,	,,	27·2
		40·35	1			,,	,,	37·8
		40·01	1			,,	,,	40·5
				38·4	1	,,	,,	53·
		38·13	1			,,	,,	55·5
				37·8	1	0·98	,,	58·
		37·64	1			,,	,,	59·4
		37·20	1	37·2	1	,,	,,	62·9
		33·55	4	33·4	1	,,	,,	92·1
		32·98	8			,,	,,	96·7
				32·8	2	,,	,,	98·
		31·26	2	31·2	1	,,	,,	28310·5
		30·20	3			,,	,,	19·0
				30·1	2	,,	,,	20·
3528·743		28·75	10	28·80	6	,,	,,	30·7
				28·6	6	,,	,,	32·
		26·16	3	26·1	2	,,	,,	51·5

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3525·45	1			0·98	8·0	28357·2
		23·78	5	3523·87	4	,,	,,	70·6
				23·6	4	,,	,,	72·
		23·34	1			,,	,,	74·2
		22·12	2	22·1	1	,,	,,	84·0
				21·2	1n	,,	,,	91·
		20·15	3	20·1	1	,,	,,	99·9
		19·32	2			,,	,,	28406·6
		19·08	1			,,	,,	08·5
		18·87	3	18·7	2	,,	,,	10·2
				17·9	1	,,	,,	18·
		17·41	2			,,	,,	22·0
		17·30	2	17·3	1	,,	,,	22·9
		16·75	3	16·6	1	,,	,,	27·3
				15·4	1b	,,	,,	38·
3513·791		13·91	2	13·9	1Fe	,,	,,	50·8
13·145		13·15	5	13·1	2	,,	,,	56·5
				11·5	1	,,	,,	70·
		11·38	2			,,	,,	70·8
				11·2	1	,,	,,	72·
				10·5	1	,,	8·1	77·9
		09·00	1			,,	,,	90·1
		07·21	1			,,	,,	28504·6
				06·9	1n	,,	,,	07·
		05·14	1 Ti ?			,,	,,	21·4
				05·0	1n	,,	,,	23·
04·811	3504·815	04·81	6	04·85	4	,,	,,	24·1
		03·61	1			,,	,,	33·9
				03·5	1n	,,	,,	35·
		01·85	1			,,	,,	48·2
				01·6	1n	,,	,,	50·
01·314		01·33	4	01·2	2Ba	,,	,,	52·5
		3499·70	1	3499·6	1	,,	,,	65·8
		99·43	1	99·4	1	,,	,,	68·0
3498·686		98·69	3	98·6	2	0·97	,,	74·0
		98·24	1	98·3	1	,,	,,	77·7
				98·0	1	,,	,,	80·
				97·2	2	,,	,,	86·
		95·99	1			,,	,,	96·1
		95·77	2	95·7	1b	,,	,,	97·9
		91·65	2	91·6	1	,,	,,	28631·7
		91·24	1			,,	,,	35·0
90·464		90·46	2	90·4	2	,,	,,	41·4
		89·01	1			,,	,,	53·3
88·915		88·91	2	88·9	2	,,	,,	54·1
87·610		87·62	3	87·6	2	,,	,,	64·8
87·387		87·40	3	87·4	1	,,	,,	66·6
				84·1	1n	,,	,,	94·
82·380		82·38	3	82·3	2	,,	,,	28707·9
82·269		82·28	3			,,	,,	31·7
				79·5	2	,,	,,	39·
78·670		78·67	3	78·6	2	,,	,,	45·9
77·798		77·76	1	77·8	16Rh	,,	,,	52·5
		76·98	1	76·7	1b	,,	,,	54·8

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3475·5	1	0·97	8·1	28765·
		3474·25	1			,,	,,	75·1
				73·2	1	,,	,,	84·
				72·9	1	,,	,,	86·
				70·8	2	,,	8·2	28804·
				69·7	1n	,,	,,	13·
3469·517		69·51	1			,,	,,	14·3
				68·8	1n	,,	,,	20·
				66·1	1	,,	,,	43·
65·585		65·59	3	65·6	2	,,	,,	46·9
		65·03	1	64·9	1n	,,	,,	51·6
						,,	,,	53·
62·335		62·35	1	62·3	2	,,	,,	74·0
				61·7	1n	,,	,,	79·
59·163		59·15	2	59·2	2	,,	,,	28900·6
		58·54	4	58·5	2	0·96	,,	05·7
				57·5	1b	,,	,,	14·
		56·27	1	56·2	1b	,,	,,	24·7
55·172		55·16	2	55·2	2	,,	,,	34·0
		53·17	1	53·1	1n	,,	,,	50·7
				52·5	1	,,	,,	56·
				51·5	1n	,,	,,	65·
		50·54	1	50·5	1n	,,	,,	72·8
49·352	3449·346	49·36	5	49·3	2	,,	,,	82·7
				48·2	1	,,	,,	92·
				46·1	1	,,	,,	29010·
45·695	45·699	45·69	3	45·6	2	,,	,,	13·6
44·616		44·60	3	44·6	1	,,	,,	22·7
				44·1	1	,,	,,	27·
				41·2	1 Pd ?	,,	,,	51·
				40·6	1	,,	,,	56·
				40·4	1n	,,	,,	58·
		39·97	1			,,	,,	61·8
39·639		39·63	2	39·5	1n	,,	,,	64·5
38·792		38·76	1			,,	,,	71·9
37·642			0			,,	,,	81·5
37·150			2			,,	,,	85·7
		35·40	1	35·5	1n	,,	,,	29100·5
		35·04	1			,,	,,	03·5
34·023			4	34·0	1n	,,	,,	12·1
				32·2	1n	,,	8·3	28·
		30·20	1			,,	,,	44·5
		30·10	1	30·0	1n	,,	,,	45·4
				28·7	1	,,	,,	57·
27·816		27·79	3	27·8	1	,,	,,	64·9
27·590		27·56	1	27·6	1	,,	,,	66·8
				26·6	1	,,	,,	75·
				25·1	1	,,	,,	88·
				24·8	1	,,	,,	90·
				23·5	2	,,	,,	29202·
22·800			1			,,	,,	07·5
		22·43	1	22·4	1	,,	,,	10·7
21·837		21·85	2	21·8	1	,,	,,	15·7
21·558						,,	,,	18·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3421·34	1			0·96	8·3	29220·0
				3420·4	1b	,,	,,	28·
				20·3	1n	,,	,,	29·
				18·8	1b	,,	,,	42·
				17·5	1	0·95	,,	53·
		15·36	1			,,	,,	71·2
				14·9	1	,,	,,	75·
3414·390		14·38	2n	14·4	1	,,	,,	79·5
12·946			0			,,	,,	91·9
12·908		12·91	2	12·8	1	,,	,,	92·2
08·906		08·90	2	08·8	2	,,	,,	29326·2
06·816		06·83	2			,,	,,	44·5
				06·7	1	,,	,,	46·
06·423		06·45	2			,,	,,	47·9
				06·3	1	,,	,,	49·
02·855			0			,,	,,	78·8
02·643	3402·654	02·66	6	02·6	2	,,	,,	80·5
	02·001	02·01	6	02·00	4	,,	,,	86·1
01·315		01·31	2	01·3	2	,,	,,	92·1
				00·6	1	,,	,,	98·
00·264		00·26	1	00·2	1	,,	,,	29401·2
3398·713		3398·71	1	3398·7	1	,,	,,	14·6
97·910		97·90	1			,,	,,	21·6
				97·6	1n	,,	,,	24·
				97·12	4	,,	,,	28·4
96·973			2			,,	,,	29·7
95·862		95·85	2	95·8	1	,,	8·4	39·3
				95·2	1n	,,	,,	45·
		94·72	2	94·6	1	,,	,,	49·1
				93·0	1	,,	,,	64·
				92·6	1	,,	,,	68·
91·401		91·41	1			,,	,,	77·9
		89·64	1			,,	,,	93·3
88·794		88·79	1	88·6	1n	,,	,,	29500·7
		88·46	1			,,	,,	03·5
87·970		88·00	6	87·9	2	,,	,,	07·7
				87·0	1n	,,	,,	16·
		86·76	1			,,	,,	18·3
86·277		86·27	2			,,	,,	22·6
86·077		86·06	2	86·1	1n	,,	,,	24 4
				86·0	2	,,	,,	25·
84·732		84·74	2	84·7	1	,,	,,	39·0
		84·16	5	84·1	2	,,	,,	41·0
				83·8	1n	,,	,,	44·
83·042			2	83·0	1	,,	,,	50·8
81·814		81·81	2	81·7	1	,,	,,	61·6
				81·3	1n	,,	,,	66·
80·674			0	80·7	1	,,	,,	71·5
				79·5	1n	,,	,,	82·
		78·80	2	78·8	1	,,	,,	87·9
		77·75	1			0·94	,,	97·1
77·088		77·10	1			,,	,,	29602·8
		76·80	1			,,	,,	05·4
75·268		75·28	1			,,	,,	18·8

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		3374·35	1			0·94	8·4	29626·9
				3374·0	1	,,	,,	30·
3373·337		73·35	1			,,	,,	35·8
		73·21	1			,,	,,	36·9
72·929						,,	,,	39·4
		72·70	1			,,	,,	41·4
		72·21	3	72·2	2	,,	,,	45·7
71·602		71·69	1			,,	,,	50·7
70·725	3370·730	70·74	8	70·70	6	,,	,,	58·7
70·340		70·37	3	70·3	1	,,	,,	62·1
				69·7	1	,,	,,	68·
68·617			2			,,	,,	77·4
				66·3	1n	,,	,,	98·
		66·04	2			,,	,,	29700·1
64·486		64·50	1	64·5	1	,,	,,	13·8
64·250		64·29	3	64·3	1	,,	,,	15·7
		63·09	1			,,	,,	26·2
62·716		62·72	1			,,	,,	29·4
61·905			0			,,	,,	36·6
61·280		61·31	3	61·2	2	,,	,,	42·0
59·876		59·90	1			,,	8·5	54·4
58·095		58·11	3	58·1	2	,,	,,	70·2
		57·69	1			,,	,,	73·9
54·042		54·05	3			,,	,,	29806·2
51·853		51·90	3			,,	,,	25·6
48·791		48·79	1			,,	,,	53·0
42·018		42·05	1			,,	,,	29913·4
40·851		40·85	1			,,	,,	24·0
39·601			0			,,	,,	35·2
		37·28	1			0·93	,,	56·0
36·282	36·301	36·30	8	36·3	2	,,	,,	64·9
		35·62	1			,,	,,	70·9
34·295		34·30	1			,,	,,	82·8
33·986		34·00	1			,,	,,	85·5
		29·35	1			,,	,,	30027·4
29·252		29·26	1			,,	,,	28·3
27·562		27·59	4	27·6	2	,,	,,	43·4
		26·65	1	26·6	1b	,,	,,	51·8
		26·55	1			,,	,,	52·7
25·644			0	25·6	1b	,,	,,	60·9
25·518			2			,,	,,	62·0
24·876		24·89	1			,,	8·6	67·7
24·486		24·51	3	24·5	2	,,	,,	71·1
		23·30	1n	23·5	2	,,	,,	82·0
22·734			1			,,	,,	87·1
22·175		22·20	1	22·2	1n	,,	,,	92·0
		20·58	1n	20·8	1b	,,	,,	30106·6
		20·05	1n			,,	,,	11·4
18·724		18·74	1n	18·8	1b	,,	,,	23·4
18·284		18·31	1n			,,	,,	27·3
17·998		18·01	1n			,,	,,	30·0
17·420		17·40	1n			,,	,,	35·4
16·822		16·81	2	16·8	1	,,	,,	40·8
15·816		15·83	2	15·9	1	,,	,,	49·8
15·555		15·56	2	15·7	1	,,	,,	52·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$−	
		3314·88	1	3314·1	2	0·93	8·6	30158·4
		13·60	1			,,	,,	70·1
3312·178		12·18	1			,,	,,	83·0
11·035		11·05	4	11·1	2	,,	,,	93·4
		09·83	1			,,	,,	30204·4
06·352		06·34	3			,,	,,	36·3
05·501		05·51	1			,,	,,	44·0
04·980			0			,,	,,	48·8
01·990			1			,,	,,	76·2
01·692	3301·708	01·70	10	01·7	2	,,	,,	78·8
3298·374			0	3297·3	2	0·92	,,	30309·4
		3293·29	1			,,	,,	56·2
91·259		91·25	1			,,	,,	74·9
		90·40	4	90·5	2	,,	,,	82·8
89·387			4			,,	,,	92·2
88·960		88·96	2			,,	8·7	96·0
88·616		88·57	1			,,	,,	99·4
		86·81	1			,,	,,	30415·9
84·680		84·68	1			,,	,,	35·7
81·028		81·06	2			,,	,,	69·4
79·590		79·55	1			,,	,,	83·1
78·086		78·09	4			,,	,,	96·9
76·533		76·54	1	75·5	1	,,	,,	30511·3
						,,	,,	
75·320		75·31	4	75·3	2	,,	,,	22·7
						,,	,,	
73·513		73·54	1	74·2	2	,,	,,	39·4
72·607		72·63	1			,,	,,	47·9
72·301		72·30	2	72·3	1	,,	,,	50·8
72·118		72·12	1			,,	,,	52·5
				72·0	1	,,	,,	54·
71·320			0			,,	,,	60·0
71·002		71·02	1			,,	,,	62·9
70·025		70·05	1			,,	,,	72·0
69·340		69·36	5	69·38	4	,,	,,	78·4
68·080	3268·078	68·10	10	68·10	8	,,	,,	90·2
67·338		67·34	1	67·40	8	,,	,,	97·2
66·890		66·89	1			,,	,,	30601·4
66·565			2			,,	,,	04·5
64·820		64·85	1	64·8	1n	,,	,,	20·7
62·880		62·89	4	63·00	4	,,	,,	39·0
62·428		62·44	8	62·48	8	,,	,,	43·3
				61·2	1	,,	,,	54·9
60·683		60·70	1	60·7	1	,,	,,	59·6
60·420		60·43	3	60·5	2	,,	,,	62·1
59·530		59·56	1n			0·91	,,	70·4
57·051		57·05	3	57·1	2	,,	,,	93·9
55·414		55·41	1			,,	,,	30709·4
55·139			0			,,	,,	11·9
55·038		55·04	3	55·1	2	,,	,,	12·9
				54·4	1n	,,	,,	18·9
				53·4	1n	,,	,,	28·4
		52·14	2			,,	8·8	40·2
		51·03	1			,,	,,	50·7
50·974			0			,,	,,	51·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3250·695		3250·50	1	3250·7	2	0·91	8·8	30754·7
48·106		48·14	2n	48·1	1	,,	,,	78·1
				47·80	4	,,	,,	82·2
		45·79	1n			,,	,,	30800·3
				45·3	2	,,	,,	05·0
43·700			0			,,	,,	20·2
42·108		42·11	1			,,	,,	35·3
				42·0	1b	,,	,,	36·4
41·933		41·94	1	41·2	2	,,	,,	37·0
41·642		41·56	1			,,	,,	40·1
41·159		41·18	3			,,	,,	44·2
39·398			0			,,	,,	61·1
38·751		38·75	3			,,	,,	67·3
		38·30	1	38·3	1n	,,	,,	71·6
				37·0	1	,,	,,	84·0
				36·6	1	,,	,,	87·8
				36·2	1n	,,	,,	91·6
34·858		34·86	1	34·8	1	,,	,,	30904·4
34·651		34·81	1			,,	,,	05·7
34·318		34·34	1	34·3	1	,,	,,	09·5
32·672		32·67	1	32·6	1	,,	,,	25·4
32·196	3232·195	32·19	8	32·20	10	,,	,,	29·9
32·072			2			,,	,,	31·1
31·543		31·56	1	31·5	1	,,	,,	36·1
31·410		31·45	1			,,	,,	37·2
30·525		30·53	1	30·6	1n	,,	,,	45·9
				30·0	1n	,,	,,	51·
29·336		29·35	1			,,	,,	57·2
				29·1	1n	,,	,,	60·
				28·8	1	,,	,,	62·
27·409		27·41	2	27·4	1	,,	,,	75·8
				27·0	1	,,	,,	81·
26·579			0	26·5	1	,,	,,	83·8
23·987		23·99	1	24·0	1	,,	,,	31008·7
				22·5	1	,,	,,	23·
		21·53	1n	21·5	1n	,,	,,	32·3
21·444			4			,,	,,	33·1
20·895			0			0·90	,,	38·5
20·408			1	20·4	1	,,	,,	43·2
20·318		20·36	2			,,	,,	43·8
19·260		19·26	1	19·3	1	,,	,,	54·2
18·153		18·15	1			,,	,,	64·9
				17·4	1	,,	,,	72·
17·177		17·17	1	17·2	1	,,	,,	74·4
				16·8	1	,,	,,	78·
				16·6	1	,,	,,	80·
16·340			0			,,	8·9	82·3
				15·8	1n	,,	,,	88·
				13·8	2n	,,	,,	31107·
		13·59	1	13·50	10	,,	,,	08·9
13·418		13·44	1			,,	,,	10·5
12·840		12·85	1	12·9	1	,,	,,	16·2
				12·6	1	,,	,,	19·
12·240			2			,,	,,	22·0

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	1/λ −	
				3209·4	1	0·90	8·9	31150·
				08·1	2	,,	,,	62·
3205·909		3205·90	1	05·9	1n	,,	,,	83·5
				05·3	1n	,,	,,	89·
04·646		04·64	1	04·6	1n	,,	,,	95·8
				04·3	1	,,	,,	99·
04·155			2			,,	,,	31200·6
		03·44	1	03·5	1n	,,	,,	07·5
02·956		02·95	2	03·0	1	,,	,,	11·9
				01·3	1	,,	,,	28·
				01·0	1n	,,	,,	31·
		00·89	1			,,	,,	32·4
		3198·26	1	3198·3	1n	,,	,,	58·1
3197·310		97·30	1	97·3	1	,,	,,	67·2
96·152		96·11″	3°	96·2	2	,,	,,	78·9
96·082						,,	,,	79·4
95·494		95·50	3	95·5	2	,,	,,	85·1
94·805		94·80	2	94·8	1	,,	,,	92·0
94·350		94·37	3	94·4	2	,,	,,	96·3
93·986		93·99	2	94·0	1	,,	,,	99·9
		91·31	1			,,	,,	31326·2
				90·9	1n	,,	,,	30·2
89·566		89·56	3	89·6	2	,,	,,	43·4
87·443		87·45	2	87·5	1	,,	,,	64·2
				87·2	2	,,	,,	67·
87·096		87·08	3			,,	,,	67·7
		86·65″	1			,,	,,	72·0
86·643			2			,,	,,	72·1
86·516			2	86·50	4	,,	,,	73·3
85·439		85·42	3	85·4″	1	,,	,,	84·0
85·304			0			,,	,,	85·3
84·458		84·46	1			,,	,,	93·6
83·905			0			,,	,,	98·2
83·661			1			,,	,,	31401·5
				83·5	1	,,	,,	03·
83·341			0			,,	,,	04·6
		82·92	1	83·0″	1	,,	,,	09·
		82·68	2	82·7	2	,,	,,	11·2
		82·35	1			,,	,,	14·4
81·907		81·99	3	82·0	2	0·89	,,	18·4
80·237		80·23	1	80·3	1	,,	9·0	35·2
		79·37	1	79·6	1b	,,	,,	43·8
78·357		78·36	1	78·3	2	,,	,,	53·8
78·184		78·18	5			,,	,,	55·5
77·522		77·51	1			,,	,,	62·1
75·781		75·77	1	75·7	1n	,,	,,	79·4
				75·0	1n	,,	,,	87·1
74·284			1			,,	,,	94·2
74·037		74·05	1	74·03	8	,,	,,	96·6
73·609			0			,,	,,	31500·9
73·306		73·31	2	73·4	1	,,	,,	03·9
		72·96	1			,,	,,	07·3
				72·6	1	,,	,,	10·9
		71·75	1			,,	,,	19·3

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3171·249			0			0·89	9·0	31524·3
				3170·6	1	,,	,,	31·
				68·9	1n	,,	,,	48·
				68·5	2	,,	,,	52·
68·390		3168·39	2			,,	,,	52·8
				68·2	1n	,,	,,	55·
66·611		66·62	3	66·65	4	,,	,,	70·5
65·772			2	65·82	8	,,	,,	78·9
				64·8	1	,,	,,	89·
64·718		64·75	2	64·7	1	,,	,,	89·2
64·550			0			,,	,,	91·1
61·837		61·86	2	61·8	1	,,	,,	31618·1
61·547		61·55	2	61·6	1	,,	,,	21·1
60·540		60·57	2			,,	,,	31·1
60·397		60·44	1	60·4	1	,,	,,	32·4
59·477		59·48	1			,,	,,	41·8
				58·6	1	,,	,,	51·
				58·2	1	,,	,,	55·
57·342		57·35	2	57·3	1	,,	,,	63·2
57·102		57·11	1	57·1	1	,,	,,	65·6
56·878		56·89	3	56·9	2	,,	,,	67·8
56·365	3156·384	56·38	8	56·35	10	,,	,,	72·9
55·450		55·45	1			,,	,,	82·2
54·666			0	54·5	1b	,,	,,	90·1
53·727		53·72	3	53·7	2	,,	,,	99·6
52·806		52·80	3	52·8	2	,,	,,	31708·8
52·181		52·19	2	52·1	2	,,	,,	15·0
51·005			0			,,	,,	26·9
50·730			0n	50·7	1	,,	,,	29·7
50·260			0			,,	,,	34·4
49·927		49·93	1n	49·9	1	,,	,,	37·8
49·365			0			,,	,,	43·4
47·601						,,	,,	61·2
46·843			0			,,	9·1	68·8
				46·5	1	,,	,,	72·
46·074		46·08	1	46·1	1	,,	,,	76·5
				45·4	1n	,,	,,	83·
44·471		44·50	2	44·5	2	,,	,,	92·6
43·169		43·19	1	43·2	1	,,	,,	31805·8
41·056		41·06	1	41·1	1	0·88	,,	27·3
40·431		40·44	1	40·5	1	,,	,,	33·6
39·745			0			,,	,,	40·6
38·157			1	38·2	1	,,	,,	56·7
37·636		37·65	1	37·7	1	,,	,,	62·0
37·421			0			,,	,,	64·2
36·785			0			,,	,,	70·7
36·334			0			,,	,,	75·2
35·126			0			,,	,,	87·5
34·805			0			,,	,,	90·8
33·953			0	34·0	1	,,	,,	99·1
				32·8	1b	,,	,,	31911·
31·995			0			,,	,,	19·4
		31·62	1n			,,	,,	23·3
31·027		31·23	3	31·3	2	,,	,,	27·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
3131·021			0			0·88	9·1	31929·4
				3130·5	1	,,	,,	35·
30·125		3130·14	1	30·2	1	,,	,,	38·4
29·348		29·35	1	29·3	1	,,	,,	46·4
				29·0	1	,,	,,	50·
28·677		28·55	1n	28·6	1	,,	,,	53·9
27·620			0			,,	,,	64·1
				27·0	1	,,	,,	70·
25·643			0	25·6	1n	,,	,,	84·3
		25·05	1n			,,	,,	90·4
				24·4	1n	,,	,,	97·
24·142		24·14	1n			,,	,,	99·7
				23·5	1n	,,	,,	32006·
				22·8	1n	,,	,,	13·
21·592			0			,,	,,	25·8
21·307			0			,,	,,	28·8
20·777		20·77	1	20·8	1	,,	,,	34·2
20·016		20·00	1	20·0	1	,,	,,	42·0
19·196			0	19·2	1n	,,	,,	50·4
				18·5	2	,,	,,	58·
18·450		18·44	2			,,	,,	58·2
18·242		18·24	1	18·3	2n	,,	,,	60·3
18·014		18·00	1			,,	,,	62·7
17·215			0			,,	,,	70·8
16·593		16·59	1	16·6	1	,,	,,	77·6
15·838						,,	,,	85·0
			0	15·6	1n	,,	,,	87·4
15·150		15·13	1	15·1	1	,,	,,	92·2
14·932		14·92	1	15·0	1	,,	,,	94·4
13·405			0	13·5	1	,,	9·2	32110·0
12·630			0			,,	,,	18·0
11·196		11·20	2	11·3	2	,,	,,	32·8
10·743		10·75	1	10·7	1	,,	,,	37·4
10·538			1	10·5	1	,,	,,	39·6
09·800		09·79	1	09·8	2	,,	,,	47·2
09·504		09·50	3	09·5	2	,,	,,	50·3
09·102		09·09	3	09·1	2	,,	,,	54·5
08·846			0	08·9	1	,,	,,	57·1
08·098		08·08	1	08·2	1	,,	,,	64·9
07·989		08·00	1			,,	,,	65·9
07·495		07·49	1	07·5	1	,,	,,	71·1
07·119			0			,,	,,	75·0
06·762			0	06·8	1n	,,	,,	78·7
06·114		06·10	3	06·2	2	,,	,,	85·4
				05·7	1	,,	,,	90·
				05·5	1	,,	,,	92·
05·098		05·09	2	05·2	1	,,	,,	95·9
				04·0	1	,,	,,	32207·
03·412		03·53	1n	03·5	1	,,	,,	12·8
02·835			2	02·9	1	,,	,,	19·4
02·503		02·50	1	02·5	1	,,	,,	22·7
		01·64	3	01·7	2	0·87	,,	31·8
				01·3	1	,,	,,	35·
		3099·38	1	3099·4	1	,,	,,	55·3

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3098·7	1	0·87	9·2	32262·
				95·2	1b	,,	,,	99·
3094·192		3094·20	1			,,	,,	32309·4
93·704		93·70	2	93·8	2	,,	,,	14·5
				92·8	1n	,,	,,	24·
92·613			0			,,	,,	25·9
				91·5	2	,,	,,	38·
91·368		91·38	1			,,	,,	38·9
90·613		90·62	1	90·7	1	,,	,,	46·8
90·416		90·42	1	90·5	1	,,	,,	48·9
90·205		90·21	2	90·3	2	,,	,,	51·1
				89·5	1n	,,	,,	58·
88·545			0	88·5	1	,,	,,	68·5
88·385		88·37	1			,,	,,	70·2
				88·0	1	,,	,,	74·
87·868			2			,,	,,	75·6
				87·3	1	,,	,,	82·
87·125			0			,,	,,	83·4
86·394		86·40	1	86·5	1	,,	,,	91·0
85·982			0			,,	,,	95·4
				85·2	2	,,	,,	32404·
85·004			2	85·0	1	,,	,,	05·7
84·715		84·72	1			,,	,,	08·7
				84·0	1	,,	,,	16·
				83·7	1	,,	9·3	19·
83·565			0			,,	,,	20·7
				82·9	1	,,	,,	28·
				82·6	1	,,	,,	31·
81·313			0			,,	,,	44·4
80·907			0			,,	,,	48·7
				80·7	1n	,,	,,	51·
80·614			0			,,	,,	51·8
		79·67	1	79·7	1	,,	,,	61·7
				79·4	1	,,	,,	65·
78·496		78·48	2	78·6	1	,,	,,	74·2
78·227		78·20	3	78·3	2	,,	,,	77·1
77·834	3077·841	77·82	4	77·82	4	,,	,,	81·1
77·557		77·55	2	77·6	2	,,	,,	84·0
77·167		77·16	2	77·2	2	,,	,,	88·2
76·845		76·86	1n	76·8	1	,,	,,	91·4
				76·5	2	,,	,,	95·
75·074		75·06	2	75·2*	2	,,	,,	32510·3
74·771			0			,,	,,	
74·192		74·21	3	74·3	2	,,	,,	13·4
				73·3	2	,,	,,	29·
72·681			0			,,	,,	35·6
71·974			1			,,	,,	34·1
70·374		70·38	1	70·5	1	,,	,,	60·0
70·049		70·05	2	70·1	2	,,	,,	63·5
		69·25	1			,,	,,	71·9
66·945		66·97	1	67·1	1	,,	,,	96·3
66·715		66·71	1	66·6	1	,,	,,	98·9
66·225		66·25	2	66·3	1	,,	,,	32604·0
65·783			0			,,	,,	08·8

* 3076·0 (10) Zn? possibly belongs to Osmium.

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
3065·391			0			0·87	9·3	32613·0
63·480			1			,,	,,	33·3
62·803		3062·80	1			0·86	,,	40·5
62·584		62·59	1			,,	,,	42·8
62·297		62·31	3	3062·23	4	,,	,,	45·8
62·039			0			,,	,,	48·7
61·814			1			,,	,,	51·1
60·412		60·44	2	60·5	2	,,	,,	65·9
60·248			0			,,	,,	67·8
58·782	3058·766	58·80	8	58·76	10	,,	,,	83·4
				58·4	1	,,	,,	88·
				58·2	1	,,	,,	90·
57·014		57·03	1	57·0	1	,,	,,	32702·3
56·315			0			,,	,,	09·8
55·726			0			,,	,,	16·2
55·326		55·33	1	55·4	2	,,	,,	20·4
				55·2	1	,,	,,	22·
55·086		55·09	1			,,	,,	23·0
54·780			0			,,	,,	26·3
54·620			1			,,	,,	28·0
54·091			2			,,	9·4	33·6
53·743			0			,,	,,	37·3
				53·5	1	,,	,,	40·
53·004			0	53·0	1	,,	,,	45·2
52·540		52·55	1	52·5	1	,,	,,	50·2
				51·4	1	,,	,,	62·
51·280		51·29	1			,,	,,	63·7
50·517		50·53	2	50·6	2	,,	,,	71·9
49·580		49·58	2	49·6	1	,,	,,	82·0
49·172		49·17	1	49·2	2	,,	,,	86·4
47·574			1	47·6	1n Fe	,,	,,	32803·6
46·200			0	46·3	1	,,	,,	17·
						,,	,,	18·4
45·898		45·90	1	46·0	1	,,	,,	21·6
45·430		45·43	1	45·4	1	,,	,,	26·7
45·031		45·04	1	45·1	1	,,	,,	31·0
44·525		44·54	1	44·6	1	,,	,,	36·4
44·191		44·20	1	44·2	1	,,	,,	40·0
44·040						,,	,,	41·7
43·793		43·78	2	43·8	1	,,	,,	44·4
43·622		43·62	2	43·7	1	,,	,,	46·2
42·860		42·85	1	42·83	8 Ti ?	,,	,,	54·5
41·021	41·023	41·03	4	41·00	8	,,	,,	74·2
40·184			1			,,	,,	83·4
36·668			2			,,	,,	32921·4
				35·3	1	,,	,,	36·
33·843			0			,,	,,	52·1
33·331			2	33·4	2	,,	,,	57·6
32·924		32·94	1	33·0	1	,,	,,	62·0
31·828			1			,,	,,	74·0
31·418		31·41	1	31·5	1	,,	,,	78·5
31·122		31·13	1	31·2	1	,,	,,	81·6
30·817		30·83	4	30·82	8	,,	,,	84·9
29·496			2			,,	,,	99·4

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
		3029·03	1	3029·1	1	0·86	9·4	33004·5
				28·8	1	,,	,,	07·
3028·032			2			,,	,,	15·3
27·790			0			,,	,,	18·1
27·659			1	27·6	2	,,	,,	19·4
				25·5	1	,,	,,	43·
24·434			0			,,	9·5	54·5
				23·7	1b	,,	,,	63·
				22·9	1n	0·85	,,	71·
22·382			0			,,	,,	77·0
21·226			0			,,	,,	89·6
				21·1	1	,,	,,	91·
				20·9	1	,,	,,	93·2
20·782			3			,,	,,	94·5
		20·63	2			,,	,,	96·2
19·498		19·50	3	19·6	2	,,	,,	33108·6
18·744			0			,,	,,	16·9
18·440			0			,,	,,	20·2
18·169	3018·155	18·16	4			,,	,,	23·3
				18·13	8	,,	,,	24·
17·380		17·38	3	17·4	2	,,	,,	31·8
15·772		15·77	1	15·8	1	,,	,,	49·5
				15·4	1n	,,	,,	54·
15·158			0			,,	,,	56·3
				14·4	1	,,	,,	65·
14·068			2	14·00	4	,,	,,	68·2
13·194		13·22	3	13·3	2	,,	,,	77·7
12·902			1			,,	,,	81·1
		12·52	1			,,	,,	85·3
		10·05	1	10·1	1b	,,	,,	33212·5
				08·7	1	,,	,,	27·
08·022		08·05	1	08·0	1	,,	,,	34·8
		07·00	1			,,	,,	46·2
05·878			0			,,	,,	58·6
05·064			0			,,	,,	67·7
04·872			0			,,	,,	69·8
03·605		03·62	1	03·6	2	,,	,,	83·7
				02·8	1	,,	,,	93·
				02·0	1	,,	,,	33302·
				01·1	1	,,	,,	12·
00·234			1	00·2	1	,,	,,	21·2
				2999·2	1	,,	,,	33·
2997·777		2997·75	2	97·8	2	,,	,,	48·7
96·385			0			,,	9·6	63·9
95·762			2	95·7	1	,,	,,	70·9
95·298			0			,,	,,	75·3
94·908			0	94·9	1	,,	,,	80·4
93·698		93·70	1	93·7	1	,,	,,	93·9
				92·5	1	,,	,,	33407·
92·240		92·24	1	92·3	1	,,	,,	10·2
90·763			1			,,	,,	26·7
89·963			0			,,	,,	35·6
				89·8	1n	,,	,,	37·
89·655		89·65	1			,,	,,	39·1

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2989·253		2989·25	1	2989·2	1	0·85	9·6	33443·0
88·396		88·37	1	88·5	1	,,	,,	53·3
		87·76	1			,,	,,	60·3
				86·2	1	,,	,,	78·
85·752		85·75	1	85·7	1	,,	,,	82·8
85·084			0	85·0	1	,,	,,	90·3
84·751			0			,,	,,	93·8
84·419		84·43	1n			,,	,,	97·7
				83·6	2	,,	,,	33507·
				83·2	1	,,	,,	11·
83·032		83·05	2			,,	,,	13·2
82·680		82·70	1			0·84	,,	17·2
82·252		82·25	1			,,	,,	22·1
				81·7	1b	,,	,,	28·
80·453			0	80·5	1	,,	,,	42·3
79·802			0			,,	,,	49·7
79·555		79·54	1	79·5	1	,,	,,	52·5
78·645		78·63	1	78·7	1	,,	,,	62·7
78·338		78·31	1	78·4	1	,,	,,	66·3
77·757		77·75	2	77·7	2	,,	,,	72·8
				77·5	1	,,	,,	76·
76·470			0			,,	,,	87·2
75·461		75·45	1	75·5	1	,,	,,	98·7
				75·3	1	,,	,,	33600·
		72·36	1	72·3	1n	,,	,,	33·7
71·098		71·10	3	71·10	4	,,	,,	48·0
70·825		70·80	1			,,	9·7	51·1
69·938			0			,,	,,	61·0
		68·55	1	68·5	1b	,,	,,	76·8
67·860			0			,,	,,	84·6
				67·0	1	,,	,,	94·
66·685			0			,,	,,	97·9
66·428			0	66·4	1	,,	,,	33700·9
66·217			0			,,	,,	03·3
				65·6	1	,,	,,	10·
65·215			1	65·3	1	,,	,,	14·7
64·890			0			,,	,,	18·4
		64·75	1	64·7	1	,,	,,	20·0
64·190		64·21	3	64·2	2	,,	,,	26·2
63·178			0	63·1	1	,,	,,	37·8
63·005			1			,,	,,	39·8
62·819			0			,,	,,	41·9
62·465		62·45	2			,,	,,	46·1
62·272		62·29	2	62·3	2	,,	,,	48·1
61·526			0			,,	,,	56·7
61·140		61·15	2	61·1	2 Cu ?	,,	,,	61·1
58·467		58·48	1			,,	,,	91·5
57·774			0			,,	,,	99·5
57·214		57·20	1	57·2	1	,,	,,	33806·0
56·629		56·62	1	56·6	1	,,	,,	12·6
				56·3	1	,,	,,	16·
55·128		55·13	1	55·1	1	,,	,,	29·8
				54·7	1	,,	,,	35·
				53·7	1	,,	,,	46·

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
2952·412		2952·45	1	2952·4	1	0·84	9·7	33860·7
				51·7	1	,,	,,	69·
51·357			1	51·3	1	,,	,,	73·0
50·986			1	50·9	1	,,	,,	77·3
		50·00	1			,,	,,	88·6
49·930		49·93	1			,,	,,	89·4
				49·8	1	,,	,,	91·
49·635			3			,,	,,	92·8
49·635		49·63	3	49·62	6	,,	,,	92·8
48·328		48·33	4	48·30	4	,,	,,	33907·8
47·277			0			,,	,,	19·9
46·705			0			,,	,,	26·5
45·437			0	45·5	1	,,	9·8	41·0
				44·2	1n	,,	,,	55·
43·756			1			,,	,,	60·4
43·291			2			,,	,,	65·8
42·981		42·96	2	43·03	4	0·83	,,	69·5
42·692			0			,,	,,	72·7
42·348		42·32	1n			,,	,,	76·8
42·267			1			,,	,,	77·6
41·989			0			,,	,,	80·8
				41·0	1b	,,	,,	92·
40·873			0			,,	,,	93·7
40·694			0			,,	,,	95·8
40·208			0			,,	,,	34001·4
39·519			0			,,	,,	09·4
38·590			0			,,	,,	20·1
38·491			0	38·4	1n	,,	,,	21·3
37·111			0	37·0	2n	,,	,,	37·3
36·817			2			,,	,,	40·7
				35·6	1b Zn?	,,	,,	55·
35·083			0			,,	,,	60·8
34·779		34·75	2	34·7	1	,,	,,	64·5
34·420			0			,,	,,	68·5
34·111			3	34·1	1	,,	,,	72·1
32·585			2	32·6	1	,,	,,	89·8
				32·4	1	,,	,,	92·
31·879			0			,,	,,	98·0
31·416		31·42	2	31·3	2	,,	,,	34103·4
30·704		30·69	1	30·6	1	,,	,,	11·8
30·334		30·32	1	30·3	1	,,	,,	16·1
29·646		29·62	2	29·5	2	,,	,,	24·2
27·370			0			,,	,,	50·5
				26·0	1	,,	,,	67·
25·708		25·69	2	25·6	2	,,	,,	70·1
25·414		25·41	1			,,	,,	73·4
24·617		24·64	1	24·6	1	,,	,,	82·6
23·298			2			,,	,,	98·1
23·109			0	23·1	1n	,,	,,	34200·4
22·818			0			,,	,,	03·8
21·193		21·20	1	21·3	1b	,,	9·9	22·6
20·974			0			,,	,,	25·2
20·204			1			,,	,,	34·3
19·935		19·94	4	19·85	8	,,	,,	37·4

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2919·380			0			0·83	9·9	34243·9
19·053			0			,,	,,	47·8
17·946		2917·94	2	2917·8	2	,,	,,	60·8
17·383		17·37	3	17·3	2	,,	,,	67·5
16·193			0			,,	,,	81·4
15·586			0	15·7	1	,,	,,	88·5
15·382			0			,,	,,	90·9
14·841		14·84	1	14·7	1	,,	,,	97·3
14·341			1			,,	,,	34303·2
13·969		13·96	1	13·8	1	,,	,,	07·6
12·470		12·47	3	12·40	8	,,	,,	25·2
11·939			0			,,	,,	31·5
11·695			0			,,	,,	34·4
11·466		11·47	1			,,	,,	37·2
11·269			0	11·2	1b	,,	,,	39·4
10·801			1			,,	,,	44·9
				10·6	2	,,	,,	47·
09·797	2909·79		1			,,	,,	56·8
				09·6	1n	,,	,,	59·
09·185		09·20	8	09·05	10	,,	,,	63·9
08·468			0			,,	,,	72·5
08·150		08·15	1	08·1	1	,,	,,	76·2
				07·1	1n	,,	,,	89·
06·909			0			,,	,,	90·9
				06·7	1	,,	,,	94·
06·103		06·09	1	06·0	1	,,	,,	34400·5
05·862		05·85	1	05·8	1	,,	,,	03·4
03·354		03·34	1	03·2	2	0·82	,,	33·1
03·193		03·21	1			,,	,,	34·8
01·455		01·45	1			,,	,,	55·6
01·308			0			,,	,,	57·3
				01·2	1	,,	,,	59·
				00·3	1	,,	,,	69·
2899·372			0	2899·3	2	,,	,,	80·3
98·023			0			,,	,,	96·4
96·183		2896·19	2	96·2	2	,,	10·0	34518·2
		95·19	1	95·3	1	,,	,,	30·0
93·014			0			,,	,,	56·0
92·466		92·47	1	92·4	1	,,	,,	62·6
91·961		91·98	1			,,	,,	68·5
90·970		91·00	1	90·9	1	,,	,,	80·3
89·654			0			,,	,,	96·2
89·280			1			,,	,,	34600·7
86·622		86·65	1n			,,	,,	32·4
86·368			0	86·3	2	,,	,,	35·4
86·182			0			,,	,,	37·8
85·295			0	85·2	2	,,	,,	48·5
84·967			0			,,	,,	52·4
84·537		84·55	1	84·4	1b Zn?	,,	,,	57·5
84·064			1			,,	,,	63·3
				83·4	1n	,,	,,	71·
				82·6	1b	,,	,,	81·
				81·8	1n	,,	,,	91·
80·477			0			,,	,,	34706·5

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
2880·327			2	2880·3	2	0·82	10·0	34708·3
79·956			0			,,	,,	12·7
				79·4	2	,,	,,	19·
79·095			0			,,	,,	23·1
78·524		2878·52	2			,,	,,	30·1
				78·4	2	,,	,,	32·
				77·7	1	,,	,,	40·
77·464		77·46	2	77·4	1	,,	,,	42·8
76·602			0			,,	,,	53·2
75·930			0			,,	,,	61·4
				75·4	2	,,	,,	68
75·083		75·07	3	75·0	2	,,	,,	71·7
74·700		74·73	1	74·7	1	,,	,,	75·4
				74·2	1	,,	,,	82·
73·534			3			,,	,,	90·4
73·126			0			,,	,,	95·3
72·529		72·52	2			,,	10·1	34802·5
				72·4	1	,,	,,	04·
				71·3	2	,,	,,	17·
				69·0	1n	,,	,,	45·
				67·5	1b	,,	,,	64·
67·216			1			,,	,,	66·9
65·892			0			,,	,,	83·0
65·802		65·80	1	65·7	1	,,	,,	84·3
65·131			0			,,	,,	92·3
64·366			2	64·3	1n	0·81	,,	34901·6
				63·4	2	,,	,,	13·
				62·0	1	,,	,,	30·
61·895			0			,,	,,	31·8
61·075		61·09	3	61·00	4	,,	,,	41·7
60·184		60·17	1	60·1	1	,,	,,	52·8
58·733			0			,,	,,	70·4
58·210			0			,,	,,	76·8
57·659		57·65	1			,,	,,	83·6
57·117			0			,,	,,	90·2
				57·0	1	,,	,,	92·
				56·8	1	,,	,,	94·
55·455		55·45	1			,,	,,	35010·6
				55·3	1	,,	,,	13·
53·971			0			,,	,,	26·0
				54·2	1n	,,	,,	29·
53·441			0	53·5	1n	,,	,,	35·3
				52·1	1n	,,	,,	52·
				51·2	1	,,	,,	63·
50·877		50·89	3	50·82	4	,,	,,	66·7
49·427		49·40	1n			,,	,,	84·8
				49·3	1	,,	,,	86·
49·175		49·15	1	49·1	1	,,	,,	87·9
48·360		48·35	2	48·3	2	,,	10·2	97·8
47·408			0			,,	,,	35109·5
46·707		46·65	1			,,	,,	18·5
46·507		46·50	2			,,	,,	20·7
				46·4	2	,,	,,	22·
				45·5	1n	,,	,,	33·

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2845·067			0			0·81	10·2	35138·4
44·802		2844·80	1			,,	,,	41·7
44·501		44·51	3			,,	,,	45·3
				2844·42	6	,,	,,	46·4
				43·0	1	,,	,,	64·
41·711		41·70	2			,,	,,	79·9
				41·5	1	,,	,,	82·
40·557			2			,,	,,	94·2
				40·0	1	,,	,,	35201·
39·792			0	39·7	1	,,	,,	03·7
38·751		38·74	4	38·70	8	,,	,,	16·6
38·283		38·28	2	38·2	2	,,	,,	22·4
37·542		37·53	2			,,	,,	31·6
				37·4	1n	,,	,,	33·
				36·2	1	,,	,,	48·
				34·3	1	,,	,,	72·
				32·6	1	,,	,,	93·
32·345		32·35	1	32·3	1	,,	,,	96·2
31·693			2			,,	,,	35304·3
				31·5	1	,,	,,	07·
				31·3	1	,,	,,	09·
				29·9	1	,,	,,	27·
29·468		29·40	2			,,	,,	32·5
29·390			2	29·3	1	,,	,,	33·1
29·138			0			,,	,,	36·2
				28·4	1	,,	,,	45·
27·670			0			,,	,,	54·6
27·038			0			,,	,,	62·5
25·437			0			,,	,,	82·5
				25·3	1	,,	,,	84·
25·013			1			,,	,,	87·9
24·918			0			0·80	,,	89·0
				24·8	1	,,	,,	91·
24·283		24·27	1	24·2	1	,,	,,	97·0
24·051			0			,,	,,	99·9
23·687			0			,,	10·3	35404·4
21·367		21·37	1			,,	,,	33·5
				21·2	2	,,	,,	36·
20·682		20·66	1			,,	,,	42·3
				20·5	1	,,	,,	44·
20·298		20·30	1	20·2	2	,,	,,	47·3
19·601			0			,,	,,	55·7
19·349			1			,,	,,	58·9
18·897			0	18·8	1	,,	,,	64·6
				18·1	1	,,	,,	75·
				17·2	1	,,	,,	86·
				16·7	2	,,	,,	92·
				16·3	1	,,	,,	97·
[15·895		15·90	2	15·8	2	,,	,,	35502·4
15·380		15·40	1n			,,	,,	08·8
14·962		19·98	1n			,,	,,	14·0
14·602			0			,,	,,	18·7
[14·318		14·34	2			,,	,,	22·1
				14·2	2	,,	,,	24·

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2813·904		2813·94	2			0·80	10·3	35527·3
				2813·8	2	,,	,,	29·
13·130			0			,,	,,	37·3
11·683			2			,,	,,	55·6
10·680			0	10·7	1b	,,	,,	68·3
10·468			0			,,	,,	71·0
09·815			0			,,	,,	79·2
09·045		09·04	3			,,	,,	89·0
				08·8	2	,,	,,	92·
08·357			0			,,	,,	97·7
07·910			0			,,	,,	35603·4
07·025		07·03	4			,,	,,	14·6
				06·9	2	,,	,,	16·
05·576			0			,,	,,	33·0
04·185		04·19	2			,,	,,	50·7
04·055			0			,,	,,	52·3
02·039			1	02·0	2 Pb	,,	,,	78·0
799·692			1			,,	,,	35707·9
96·833		2796·84	2			,,	10·4	44·3
96·221			0			,,	,,	52·2
				2795·9	2b	,,	,,	56·
95·275			1			,,	,,	64·3
94·309		94·30	1	94·2	1n Pt	,,	,,	76·7
94·091		94·10	1			,,	,,	79·3
92·844			0			,,	,,	95·4
				92·1	1n	,,	,,	35805·
91·007			2			,,	,,	19·0
89·620			0			,,	,,	36·8
87·153			1			,,	,,	68·5
86·904		86·90	1			,,	,,	71·7
				86·8	1	,,	,,	73·
86·414		86·41	3	86·4	2	,,	,,	78·0
86·061			1			,,	,,	82·6
85·147			2	85·2	1 Ba	,,	,,	94·3
				84·8	1n	,,	,,	99·
				84·0	2	,,	,,	35909·
82·658		82·69	2	82·7	2	0·79	,,	26·2
81·972						,,	,,	35·3
				81·2	1n	,,	,,	45·
80·970			0			,,	,,	48·3
80·269			0			,,	,,	57·3
79·584			0			,,	,,	66·2
79·197			1			,,	,,	71·2
77·011		77·01	1			,,	,,	99·5
75·004		75·01	1			,,	10·5	36025·4
74·488		74·50	1			,,	,,	32·1
74·257		74·25	1			,,	,,	35·2
74·125		74·13	1			,,	,,	36·9
73·592			0			,,	,,	43·8
73·176		73·18	1			,,	,,	49·2
71·869			0			,,	,,	66·2
71·150			1			,,	,,	75·6
70·825			4			,,	,,	79·8
70·213		70·22	1			,,	,,	87·8

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
2769·975		2770·00	1			0·79	10·5	36090·7
69·385			3			,,	,,	98·6
68·369			0			,,	,,	36111·8
67·236		67·25	1			,,	,,	26·5
66·650			1			,,	,,	34·3
65·541		65·55	1	2765·5	1	,,	,,	48·7
65·143			2	65·2	2	,,	,,	54·0
64·637			0			,,	,,	60·6
		64·15	2	64·1	1	,,	,,	67·0
64·032			2			,,	,,	68·5
		64·05	1			,,	,,	68·3
63·371		63·39	2	63·4	2	,,	,,	77·1
62·745			0			,,	,,	85·4
61·530		61·54	2	61·6	2	,,	,,	36201·2
61·184		61·21	1			,,	,,	05·5
60·168			0			,,	,,	19·2
58·923		58·95	1			,,	,,	35·3
58·775			0			,,	,,	37·5
57·902		57·91	1			,,	,,	48·9
56·095			0			,,	,,	73·8
55·680			0			,,	,,	78·2
54·780			0			,,	,,	90·0
53·792		53·83	1			,,	,,	36302·3
51·875			0			,,	,,	28·4
51·246		51·25	1	51·3	1	,,	10·6	36·5
50·970			0			,,	,,	40·2
				50·6	1	,,	,,	45·
				50·4	1	,,	,,	48·
				49·4	2	,,	,,	61·
		49·30	1			,,	,,	62·3
				49·1	1	,,	,,	65·
48·964		48·97	1			,,	,,	66·7
48·003		48·01	1	48·1	2	,,	,,	79·5
45·632			1			,,	,,	36410·9
44·981			0			,,	,,	19·5
				44·6	1n	,,	,,	25·
				44·2	1	,,	,,	30·
42·801			0			,,	,,	48·5
				42·6	1	,,	,,	51·
				42·3	1	,,	,,	55·
		41·50	1	41·5	1	0·78	,,	65·8
40·862		40·84	1			,,	,,	74·4
40·701		40·70	1	40·7	2	,,	,,	76·4
40·414		40·42	1	40·4	2	,,	,,	80·2
38·636			2	38·6	1n	,,	,,	36503·9
38·427			0			,,	,,	06·7
				37·8	1	,,	,,	15·
				37·5	1	,,	,,	19·
				37·1	1	,,	,,	24·
				36·7	1n	,,	,,	30·
36·479			1			,,	,,	32·7
35·848			0			,,	,,	41·1
32·905		32·90	3	32·9	2	,,	,,	80·5
31·931			0			,,	,,	93·5

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2731·467			1			0·78	10·6	36599·8
				2731·38	4	,,	,,	36600·9
30·782			4	30·8	2	,,	,,	08·9
29·093			0			,,	,,	31·6
		2728·63	1			,,	,,	37·8
28·364			2			,,	,,	41·4
				28·2	2n	,,	,,	44·
27·357			0			,,	,,	54·9
				23·8	1	,,	10·7	36703·
22·867			0	22·9	1n	,,	,,	15·3
22·700			0			,,	,,	17·5
21·959		21·97	3	22·0	2	,,	,,	27·5
				21·1	1	,,	,,	39·
20·578			1			,,	,,	46·2
20·130		20·15	3	20·2	2	,,	,,	52·2
				19·2	1 Pt ?	,,	,,	65·
				19·0	1	,,	,,	68·
18·796			1			,,	,,	70·3
				18·6	1	,,	,,	73·
17·839			0			,,	,,	83·2
17·488			0			,,	,,	88·0
17·162			0			,,	,,	92·4
				16·0	1	,,	,,	36808·
				15·9	1	,,	,,	10·
15·726		15·72	1			,,	,,	11·9
15·471		15·46	2n	15·5	1	,,	,,	15·4
14·997			0			,,	,,	21·8
14·744		14·74	2	14·7	2	,,	,,	25·2
13·300			0			,,	,,	44·8
12·848			0			,,	,,	50·9
				11·1	1n	,,	,,	75·
				10·5	1	,,	,,	83·
09·953		09·96	1	10·0	1	,,	,,	90·3
				09·2	1n	,,	,,	36901·
08·276		08·27	1	08·25	4	,,	,,	13·2
07·519		07·51	1	07·6	1	,,	,,	23·5
				07·2	1	,,	,,	28·
06·804		06·80	2	06·8	2	,,	,,	33·3
		06·04	1			,,	,,	44·2
05·547			0	05·6	1n	,,	,,	49·7
04·695			9			,,	,,	62·0
04·551		04·55	1			,,	,,	64·0
				04·2	1	,,	,,	69·
03·203			0	03·2	1n	,,	10·8	82·3
				03·0	1	,,	,,	85·
		02·92	1			,,	,,	86·2
				02·7	1	,,	,,	89·
				02·6	1 Pt ?	,,	,,	91·
		02·50	1			,,	,,	92·0
				01·4	1	,,	,,	37007·
00·840		00·82	1	00·9	1	,,	,,	14·9
				00·6	1	,,	,,	18·
2699·688		2699·68	2	2699·7	2	,,	,,	30·6
				98·5	1n	,,	,,	47·

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2698·321			0			0·77	10·8	37049·3
				2698·0	1	,,	,,	54·
				97·6	1	,,	,,	59·
97·338		2697·34	1	97·4	1	,,	,,	62·8
				97·0	1	,,	,,	67·
96·709			0			,,	,,	71·4
				96·4	1	,,	,,	76·
				95·0	1	,,	,,	95·
94·854		94·86	1			,,	,,	96·9
				94·7	1	,,	,,	99·
94·615		94·61	1			,,	,,	37100·3
				92·9	2	,,	,,	24·
92·790		92·77	1			,,	,,	25·5
92·021			0	92·1	2	,,	,,	36·0
91·483			0	91·5	2	,,	,,	43·4
89·904		89·89	3	89·85	4	,,	,,	65·3
89·447		89·44	1	89·4	1 Cu ?	,,	,,	71·6
				89·2	1n	,,	,,	75·
88·174		88·18	1	88·2	1	,,	,,	89·1
87·277			0	87·3	1	,,	,,	37201·6
86·777			0	86·8	1n	,,	,,	08·5
86·624			0			,,	,,	10·6
·85·973			0	86·0	1	,,	,,	19·7
84·497			2			,,	,,	40·1
83·974			0			,,	,,	47·4
				82·8	1	,,	,,	64·
82·279		82·30	1	82·3	1	,,	,,	70·9
80·806			0			,,	,,	91·4
79·825		79·83	1n	79·8	1	,,	,,	37305·0
79·457			0	79·5	1	,,	,,	10·2
78·870			0			,,	10·9	18·3
77·473			0	77·5	2	,,	,,	37·8
74·969		·75·00	2	75·0	2	,,	,,	72·5
74·793			0			,,	,,	75·2
74·654		74·68	2	74·7	2	,,	,,	76·9
				73·7	1	,,	,,	90·
				73·4	1	,,	,,	95·
72·145			0			,,	,,	37412·2
				71·9	1	,,	,,	16·
				71·3	1b	,,	,,	24·
70·640		70·66	1n			,,	,,	33·2
				69·9	1	,,	,,	44·
69·606		69·61	1	69·6	1	,,	,,	47·8
69·158			0			,,	,,	54·1
67·593			0	67·6	2	,,	,,	76·1
				67·0	1	,,	,,	84·
				66·8	1	,,	,,	87·
66·295		66·31	1n	66·3	1	,,	,,	94·2
				66·2	1	,,	,,	96·
66·079		66·08	1n			,,	,,	97·4
65·370			0			,,	,,	37507·3
64·879			4			,,	,,	14·3
64·390			0	64·5	1n	,,	,,	21·1
63·950			0	64·0	1n	,,	,,	27·3

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
2663·314			2	2663·3	6 Pb	0·77	10·9	37536·4
62·653		2662·63	1	62·6	1	,,	,,	45·8
62·069			2	62·0	1	,,	,,	53·9
				61·8	1	,,	,,	58·
		61·29	2	61·3	2	,,	,,	64·9
61·011		61·05	1	61·1	1	,,	,,	68·5
59·924		59·91	2	60·0	2	,,	,,	84·3
		59·55	2 Pt ?	59·6	1	,,	,,	89·4
58·682		58·69	3	58·68	6 Pd ?	,,	,,	37601·7
57·203			0					22·7
56·774		56·76	2	56·7	2	,,	,,	28·8
				56·3	1n	,,	,,	35·
55·879		55·89	1n	55·9	1	,,	,,	41·3
55·297		55·29	1n	55·6	1	,,	,,	49·7
				55·3	1	,,	,,	50·
				54·7	1	0·76	11·0	58·
53·860		53·86	1	53·8	1	,,	,,	70·0
53·388			1	53·3	1	,,	,,	76·7
53·068		53·06	1	53·1	1	,,	,,	81·2
				52·5	1	,,	,,	89·
52·369			0			,,	,,	91·1
51·562			0			,,	,,	37702·6
				51·2	1	,,	,,	08·
				51·1	1	,,	,,	09·
50·754			0	50·7	1n	,,	,,	14·1
				49·7	1n	,,	,,	29·
49·428		49·43	2	49·4	2	,,	,,	33·0
				48·2	1	,,	,,	50·
47·817		47·82	2	47·8	2	,,	,,	55·9
		47·00	2 Pt ?	47·0	2 Pt ?	,,	,,	67·6
				46·4	1	,,	,,	76·
				45·7	1n	,,	,,	86·
45·207			0	45·3	1n	,,	,,	93·2
44·211		44·23	3	44·13	4	,,	,,	37807·2
43·727		43·74	1	43·7	1	,,	,,	14·3
43·132			1			,,	,,	22·9
				42·8	1	,,	,,	28·
41·700			2	41·6	1	,,	,,	43·4
41·271		41·30	1n	41·3″	1	,,	,,	49·4
40·625			0	40·6	2	,,	,,	58·8
40·079			0			,,	,,	66·7
39·533			0			,,	,,	74·5
				39·2	2	,,	,,	79·
38·428			0	38·4	2	,,	,,	90·4
38·081		38·10	1	38·0	1	,,	,,	95·2
37·223		37·25	3	37·12	6	,,	,,	37907·5
34·547		34·55	1n			,,	,,	46·2
34·375		34·38	1n	34·4	1	,,	,,	48·6
				33·2	1	,,	,,	66·
32·994		32·99	1	33·0	1	,,	,,	68·6
				32·0	1	,,	,,	83·
				31·4	1	,,	11·1	91·
				31·2	1	,,	,,	94·
				29·5	1	,,	,,	38019·

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
				2628·5	1	0·76	11·1	38032·5
2628·377		2628·56	2	28·4	1 Fe	,,	,,	35·2
				27·8	1	,,	,,	44·
				27·3	1	,,	,,	51·
				26·5	1	,,	,,	62·
25·436			0			,,	,,	77·8
24·677			0	24·7	1n	,,	,,	88·8
				24·3	1	,,	,,	94·
23·711			0			,,	,,	38102·8
				23·6	1n	,,	,,	05·
				23·3	1	,,	,,	09·
21·912		21·95	2	21·9	1	,,	,,	28·7
21·473		21·50	1	21·5	1	,,	,,	35·2
20·723		20·75	1	20·7	1	,,	,,	46·1
20·035		20·05	3	20·1	1	,,	,,	56·2
				19·5	1	,,	,,	64·
18·923			0			,,	,,	72·5
18·435			0			,,	,,	79·6
17·895			0	17·8	2	,,	,,	87·5
17·062			0			,,	,,	38200·0
		16·05	1n			,,	,,	14·5
15·122			0			,,	,,	28·0
14·158			0			,,	,,	42·1
13·167		13·17	3	13·1	2	,,	,,	56·6
12·732		12·75	2			,,	,,	62·9
				12·6	1	,,	,,	65·
11·410		11·45	1					82·1
10·881		10·89	2	10·8	1	,,	,,	90·1
09·669		09·67	2			0·75	,,	38307·9
09·303		09·30	1			,,	11·2	13·2
08·342			0			,,	,,	27·3
				05·2	1b	,,	,,	74·
05·051			0			,,	,,	75·8
04·701		04·70	1			,,	,,	80·9
03·554			0			,,	,,	97·8
03·323		03·30	1			,,	,,	38401·2
				03·1	1	,,	,,	05·
02·444		02·43	1			,,	,,	14·3
00·855		00·86	1			,,	,,	37·7
00·5[illegible]0		00·56	1			,,	,,	42·1
00·008		00·03	1			,,	,,	50·1
				2599·9	1	,,	,,	52·
		2599·25	1			,,	,,	61·4
2597·9[illegible]0			0	97·9	1	,,	,,	81·4
97·664		97·69	1			,,	,,	84·7
				97·5	1	,,	,,	87·
		97·38	1			,,	,,	89·1
97·319		97·32	1			,,	,,	90·0
97·092			0			,,	,,	93·4
96·783		96·81	1	96·7	1	,,	,,	97·8
96·474			0			,,	,,	38502·6
				96·3	1	,,	,,	05·
96·101		96·11	1			,,	,,	08·0
				96·0	1	,,	,,	10·

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
				2595·9	1	0·75	11·2	38511·
2594·238		2594·25	1	94·2	1	,,	,,	35·7
94·000			0			,,	,,	39·3
				92·7	1	,,	,,	59·
92·082		92·10	1	92·1	1	,,	,,	67·7
90·859		90·87	2			,,	,,	86·0
				90·7	2	,,	,,	88·
89·595		89·59	1	89·6	1n	,,	,,	38604·9
89·495		89·50	1			,,	,,	06·3
88·517			0			,,	11·3	20·9
				88·4	1	,,	,,	23·
87·575		87·56	1n	87·5	1	,,	,,	35·0
86·995			0	86·9	1	,,	,,	43·6
				86·1	1	,,	,,	57·0
				83·6	1n	,,	,,	94·
82·027		82·06	2	82·0	1	,,	,,	38717·7
81·154		81·17	1	81·1	1	,,	,,	30·9
80·120			2	80·08	4	,,	,,	46·6
79·839			0			,,	,,	50·8
78·430		78·42	1	78·4	2	,,	,,	72·1
78·284		78·26	1			,,	,,	74·4
77·141			0			,,	,,	91·4
				76·5	1	,,	,,	38801·
74·852			1			,,	,,	25·9
73·601			0			,,	,,	44·8
73·198			0			,,	,,	50·8
72·572		72·60	1n			,,	,,	60·4
71·878		71·90	1	71·8	1	,,	,,	70·6
71·611			0			,,	,,	74·8
71·244		71·25	1			,,	,,	80·3
70·855			0			,,	,,	86·3
68·937		68·95	1	69·0	1	,,	,,	38915·2
67·335			0			,,	11·4	39·5
				67·0	1	,,	,,	45·
66·595		66·62	2	66·6	1	,,	,,	50·5
65·816			0			,,	,,	62·6
65·261		65·28	1			,,	,,	70·8
64·469		64·50	1			0·74	,,	82·8
64·287			1			,,	,,	85·8
63·257			2	63·3	2	,,	,,	39000·8
62·771		62·78	1			,,	,,	08·8
60·831			0			,,	,,	38·4
60·578			0			,,	,,	42·3
60·308			0			,,	,,	46·4
58·191		58·20	1			,,	,,	78·6
57·868		57·87	1			,,	,,	83·6
56·179		56·17	1			,,	,,	39109·6
55·902		55·90	1			,,	,,	13·7
55·378		55·35	1			,,	,,	22·0
55·205		55·20	1			,,	,,	24·4
54·558		54·55	1			,,	,,	34·4
50·873			0			,,	,,	90·9
48·930			1	48·9	2	,,	11·5	39220·6
				48·4	1	,,	,,	29·

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2548·193			2	2548·2	1	0·74	11·5	39231·9
		2547·80	1	47·7	1	,,	,,	38·0
47·289			0			,,	,,	45·9
				47·1	1	,,	,,	49·
				46·9	1	,,	,,	52·
46·261		46·25	1	46·2	1n	,,	,,	61·9
				45·0	1 Cu ?	,,	,,	81·
44·067			4	44·1	1	,,	,,	95·4
43·892		43·90	1	43·9	1	,,	,,	98·3
				43·0	1	,,	,,	39312·
42·592		42·60	1	42·6	2	,,	,,	18·4
				42·2	1	,,	,,	25·
41·747			0			,,	,,	31·5
				41·6	1	,,	,,	34·
40·835		40·85	1	40·8	1n	,,	,,	45·5
				40·4	1	,,	,,	52·
40·230		40·25	1	40·2	1	,,	,,	54·9
39·751			0			,,	,,	62·4
				39·0	1	,,	,,	74·
				38·8	1	,,	,,	77·
38·500			0			,,	,,	81·8
38·174		38·17	1			,,	,,	86·9
38·087		38·10	3	38·10	4	,,	,,	88·1
				36·8	1n Zn?	,,	,,	39408·
36·184			0			,,	,,	17·8
35·484			0	35·5	1	,,	,,	28·7
34·270		34·25	1			,,	,,	47·7
32·732			0			,,	,,	71·6
		32·53	1	32·5	1	,,	,,	74·7
32·083			1	32·0	2	,,	,,	82·
				31·5	1n	,,	,,	91·
				29·6	1 Cu ?	,,	11·6	39520·
29·047			0			,,	,,	29·0
27·832			1	27·8	1	,,	,,	48·0
27·335			0			,,	,,	55·8
27·174		27·15	1			,,	,,	58·5
26·833			0			,,	,,	63·6
				26·4	1	,,	,,	70·
		26·10	1	26·1	1	,,	,,	75·1
				25·4	1	,,	,,	86·
24·879						,,	,,	94·3
				24·3	1	,,	,,	39603·
				22·9	1	,,	,,	25·
20·156			0			,,	,,	68·5
19·886		19·86	1	19·9	1	,,	,,	72·9
				19·1	2	,,	,,	85·
18·533		18·52	1	18·5	2	,,	,,	94·1
18·006		18·00	1	18·0	1	,,	,,	39702·4
15·140		15·13	1	15·1	1	0·73	,,	47·7
13·340		13·34	1	13·3	2	,,	,,	76·1
12·970		12·98	1	13·0	1	,,	,,	81·9
				12·3	1n Zn?	,,	,,	93·
				10·8	1	,,	11·7	39816·
10·591			0	10·5	1	,,	,,	19·6

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2510·024		2510·04	1			0·73	11·7	39828·4
09·809			0			,,	,,	32·0
				2509·7	2	,,	,,	34·
08·707		08·71	1			,,	,,	49·4
07·282			0	07·2	1	,,	,,	72·1
06·767			0			,,	,,	80·3
06·481			0	06·5	1n	,,	,,	84·6
04·603			0			,,	,,	39914·8
		04·59	1			,,	,,	15·0
04·486		04·49	1			,,	,,	16·6
03·766			2	03·7	1	,,	,,	28·7
02·382		02·38	1			,,	,,	50·2
01·963			0			,,	,,	56·9
01·016		01·00	1			,,	,,	72·2
00·820		00·80	1			,,	,,	75·3
2498·512		00·01	1			,,	,,	88·1
[illegible]		2498·50	2			,,	,,	40012·2
				2497·1	2	,,	,,	35·
96·425			1			,,	,,	45·6
				95·1	1b	,,	,,	69·
93·935			0			,,	11·8	85·5
93·710		93·70	1			,,	,,	89·2
				93·6	1	,,	,,	91·
92·477		92·46	1	92·5	1	,,	,,	40109·1
				92·1	1	,,	,,	15·
91·789		91·76	1			,,	,,	20·2
91·106		91·11	1			,,	,,	31·0
				90·7	1n	,,	,,	38·
				89·7	1	,,	,,	54·
89·370			0	89·3	2	,,	,,	59·6
89·113			0			,,	,,	63·1
88·890			0			,,	,,	66·8
88·640		88·64	3	88·65	4	,,	,,	70·8
88·415			1			,,	,,	74·4
				88·3	1n	,,	,,	76·
86·326		86·33	2	86·3	4 Zn	,,	,,	40208·2
				85·7	1	,,	,,	18·
85·424			0			,,	,,	22·8
				85·3	1	,,	,,	25·
				84·3	1n	,,	,,	41·
				83·4	1	,,	,,	56·
				82·8	1	,,	,,	65·
82·524		82·50	1	82·5	1	,,	,,	70·0
81·892		81·89	1	81·9	1	,,	,,	80·1
80·825			0			,,	,,	97·4
				79·9	1	,,	,,	40312·
77·100			0			,,	,,	58·0
76·923		76·93	1	76·9	2	,,	,,	60·8
76·179			0			,,	11·9	72·9
75·769			0			,,	,,	79·6
75·064			0	75·1	1	,,	,,	91·1
				74·9	1	,,	,,	94·
				74·1	1	,,	,,	40407·

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda}-$	
2473·756			0			0·73	11·9	40412·6
				2473·6	1	,,	,,	15·
				73·3	1	,,	,,	20·
				72·9	1	,,	,,	26·
72·378		2472·37	1	72·4	1	,,	,,	35·0
70·925			0			,,	,,	58·8
				70·8	1	,,	,,	61·
				70·5	1	,,	,,	66·
				70·2	1	,,	,,	71·
				69·6	1	0·72	,,	80·
				68·92	4	,,	,,	92·
68·209			0			,,	,,	40503·3
67·420			0			,,	,,	16·3
66·535			0			,,	,,	30·8
				65·3	2	,,	,,	51·
64·577		64·59	1n			,,	,,	62·9
		64·11	1n			,,	,,	70·7
61·508		61·51	2	61·5	2	,,	,,	40613·6
59·940			0			,,	12·0	39·4
				58·8	1	,,	,,	58·
57·804			0			,,	,,	74·7
				57·7	2	,,	,,	76·
57·273			0			,,	,,	83·5
56·555		56·55	1			,,	,,	95·4
55·716			0			,,	,,	40709·3
55·422			0			,,	,,	14·2
				55·1	2	,,	,,	20·
55·002			1			,,	,,	22·2
				54·7	1	,,	,,	26·
54·278			0			,,	,,	33·2
53·989		54·00	1	54·0	1	,,	,,	37·9
				53·5	2	,,	,,	46·
53·392			0			,,	,,	47·9
52·869			0			,,	,,	56·6
				52·7	1	,,	,,	59·
		51·84	1			,,	,,	73·7
				51·7	1	,,	,,	76·
				51·4	2	,,	,,	81·
51·290			0			,,	,,	82·8
50·833	2450·83	50·85	1	50·8	2	,,	,,	90·3
50·581			0			,,	,,	94·6
49·987			0			,,	,,	40804·5
				48·5	1	,,	,,	29·
				47·4	1	,,	,,	48·
				46·4	1n	,,	,,	64·
46·125		46·11	1	46·1	1	,,	,,	69·1
45·980		46·00	1			,,	,,	71·4
				45·2	1n Zn?	,,	,,	84·
				44·6	1	,,	,,	94·
				44·3	1	,,	,,	40900·
				43·8	2	,,	12·1	08
42·104			0			,,	,,	36·2
				41·1	1	,,	,,	53·
40·913			0			,,	,,	56·2

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2440·8	2	0·72	12·1	40958·
				40·5	1	,,	,,	63·
2437·798			0			,,	,,	41008·5
				35·7	1	,,	,,	44·
34·731			0			,,	,,	60·2
34·605			0			,,	,,	62·3
				32·9	2	,,	,,	91·
31·699		2431·70	1	31·7	1	,,	,,	41111·4
31·299		31·30	1	31·3	1	,,	,,	18·2
29·801			0			,,	,,	43·5
29·025			0			,,	,,	56·7
				28·4	1	,,	,,	67·
27·997			0	28·0	2	,,	12·2	64·0
27·386			0			,,	,,	84·4
27·280			0			,,	,,	86·2
26·907		26·90	1			,,	,,	92·6
26·297			0			,,	,,	41202·9
		25·06	1	25·1	2	,,	,,	23·9
24·820		24·82	1			,,	,,	28·0
24·655		24·67	1	24·7	1	,,	,,	30·7
				24·2	2	,,	,,	39·
24·102			0			,,	,,	40·2
23·158			2	23·13	4	,,	,,	56·3
22·106			0			,,	,,	74·2
21·949			0			0·71	,,	76·9
				21·7	1n	,,	,,	81·
21·268			0			,,	,,	88·5
				20·7	1	,,	,,	98·
20·137			0	20·2	1	,,	,,	41307·8
				19·8	1	,,	,,	14·
18·618		18·61	1	18·6	1	,,	,,	33·8
18·457			0			,,	,,	36·5
18·081		18·07	1	18·1	1	,,	,,	43·0
				16·8	1	,,	,,	65·
15·436			0	15·5	1	,,	,,	88·2
14·639		14·63	1n	14·7	1	,,	,,	41401·9
14·198			0	14·1	1	,,	,,	09·4
14·042			0			,,	,,	12·1
11·992			0			,,	12·3	47·2
11·536			1			,,	,,	55·0
10·282			0			,,	,,	76·6
				09·6	2n	,,	,,	88·
09·476			0			,,	,,	90·5
09·010			1			,,	,,	98·5
08·764		08·76	1			,,	,,	41502·8
06·053		06·06	1n			,,	,,	49·5
05·531		05·55	1			,,	,,	58·2
05·176			0			,,	,,	64·7
03·944		03·95	1			,,	,,	86·0
02·620			0			,,	,,	41608·9
02·328		02·31	1			,,	,,	14·1
01·219		01·23	1	01·2	2	,,	,,	33·1
2398·300			0			,,	,,	83·9

OSMIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
2397·730			0			0·71	12·4	41693·7
96·855		2396·88	1n			,,	,,	41708·7
95·969		95·99	1	2395·9	1	,,	,,	24·2
94·379		94·40	1	94·4	1	,,	,,	51·9
93·986			0			,,	,,	58·9
				92·6	1	,,	,,	83·
				91·9	1	,,	,,	95·
91·248			0			,,	,,	41806·8
87·378		87·37	1	87·4	1	,,	,,	74·6
				86·1	1	,,	,,	97·
84·715		84·71	1	84·7	1n	,,	,,	41921·4
				83·2	1n	,,	12·5	48·
82·595			0			,,	,,	58·5
79·931		79·90	1n			,,	,,	42005·8
79·730		79·70	1n			,,	,,	09·3
79·482		79·46	1	79·5	1	,,	,,	13·6
78·842			0	78·9	1	,,	,,	24·8
				78·6	1	,,	,,	29·
77·704		77·66	1	77·7	1	,,	,,	45·3
77·128		77·11	1	77·2	2	,,	,,	55·2
76·398			0			,,	,,	68·0
				76·2	1	,,	,,	71·
				75·2	2	,,	,,	89·
				74·8	1	,,	,,	96·
				73·0	1n	0·70	,,	42128·
				72·0	1	,,	,,	46·
71·270		71·27	1	71·3	1	,,	,,	59·0
70·796		70·79	1	70·7	1	,,	,,	67·4
69·346		69·34	1	69·3	1	,,	,,	93·3
67·434		67·46	1	67·40	6	,,	12·6	42227·0
63·421			1			,,	,,	98·9
63·128			0			,,	,,	42304·2
62·855		62·85	1			,,	,,	09·1
62·498		62·50	1			,,	,,	15·5
				58·7	2	,,	,,	84·
				57·9	1	,,	,,	98·
57·344		57·35	1n			,,	,,	42408·0
56·999		57·00	1n			,,	,,	14·2
55·378			0	55·4	2	,,	,,	43·4
		53·10	1			,,	12·7	84·4
51·826			0			,,	,,	42507·4
51·678			0			,,	,,	10·1
50·323			0	50·3	2	,,	,,	34·7
47·480		47·50	1			,,	,,	86·0
45·855			0			,,	,,	42615·7
43·831			1	43·9	1	,,	,,	52·5
42·043			0			,,	,,	85·1
40·732			0			,,	12·8	42708·9
38·723			1			,,	,,	45·6
36·876		36·89	1n			,,	,,	79·2
34·640			1			,,	,,	42820·4
				33·0	1	,,	,,	50·
32·288			1			,,	,,	63·5
29·356			0			,,	,,	42917·5

OSMIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
2327·081			0			0·70	12·9	42959·4
25·636			0			0·69	,,	86·1
		2324·37	1n			,,	,,	43009·5
		24·07	1n			,,	,,	15·1
				2320·4	1	,,	,,	83·
				13·9	2	,,	13·0	43204·
		08·40	1n			,,	,,	43307·1
				06·2	2	,,	,,	48·
				05·0	1	,,	,,	71·
				93·7	1	,,	13·1	43585·
				88·2	1	,,	13·2	43689·
				86·6	1n	,,	,,	43720·
				85·6	1n	,,	,,	39·
				85·0	1n	,,	,,	50·
		2283·76	1			,,	,,	74·2
				83·3	2	,,	,,	83·
		82·35	1	82·41	4	,,	,,	43801·
				79·2	1	,,	,,	62·
				77·4	1	0·68	,,	97·
				72·6	2	,,	13·3	43989·
				70·8	1	,,	,,	44024·
				58·5	1	,,	13·4	44264·
				52·2	1	,,	,,	44388·
		50·97	1			,,	13·5	44411·8
				04·5	2	0·67	13·8	45348·

RHODIUM.

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Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
5983·830			4			1·63	4·5	16707·2
52·791			0			1·62	4·6	94·2
41·743			1			,,	,,	16825·5
18·698			1			1·61	,,	91·0
07·478			1			,,	,,	16923·1
5899·128			1			,,	,,	47·1
71·947			1			1·60	,,	17025·5

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
5833·808			1n			1·59	4·7	17136·8
31·730			4			,,	,,	42·9
21·991			2			,,	,,	71·6
07·058			4			1·58	,,	17215·7
03·482			2			,,	,,	26·3
5797·668			2			,,	,,	43·6
95·936			2			,,	,,	48·8
92·824			4			,,	,,	58·0
55·894			0			1·57	,,	17368·8
42·985			0			,,	,,	17407·9
30·600			2			1·56	,,	45·5
27·466			3			,,	,,	55·0
26·875			1n			,,	,,	56·8
18·038			0			,,	4·8	83·8
13·799			1n			,,	,,	96·8
08·930			0n			,,	,,	17511·7
00·628			4n			1·55	,,	37·1
5695·823			1			,,	,,	51·9
86·543			4			,,	,,	80·6
59·924			2n			1·54	,,	17663·3
59·791			4			,,	,,	63·7
51·466			1n			,,	,,	89·7
34·847			2			,,	,,	17741·9
32·954			2			,,	,,	47·9
26·254			2			1·53	,,	69·0
08·541			4			,,	4·9	17825·0
07·898			3			,,	,,	27·1
05·214			0			,,	,,	35·6
5599·620			6n			,,	,,	53·5
95·043			2n			,,	,,	68·1
68·495			0			1·52	,,	17953·3
57·364			1n			,,	,,	89·2
56·968			3			,,	,,	90·5
55·288			0			,,	,,	96·0
44·797			6b			1·51	,,	18030·0
42·260			0			,,	,,	38·2
35·235			5n			,,	,,	61·2
34·074			1n			,,	,,	65·0
04·845			4n			1·50	5·0	18160·8
03·776			2n			,,	,,	64·3
5497·197			0			,,	,,	86·2
92·048			2n			,,	,,	18203·1
84·421			4n			,,	,,	28·5
81·602			2n			,,	,,	37·8
80·997			0			,,	,,	39·9
75·318			2n			1·49	,,	58·8
71·040			5n			,,	,,	73·0
68·921			2n			,,	,,	80·1
68·288			3n			,,	,,	82·2
45·424			4n			,,	,,	18359·0
44·508			2n			,,	,,	62·1
41·547			4n			,,	,,	72·1
39·783			4			1·48	,,	78·1
32·224			2n			,,	,,	18403·7

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
5431·813			2n			1·48	5·0	18405·1
25·636			4n			,,	,,	26·0
24·910			4			,,	,,	28·5
23·483			2n			,,	,,	33·3
08·972			2			,,	,,	82·8
04·898			4n			,,	,,	96·7
5390·622			5			1·47	5·1	18545·6
84·214			0			,,	,,	67·7
81·683			0			,,	,,	76·4
79·275			5			,,	,,	84·8
69·470			1			,,	,,	18617·7
64·290			0			,,	,,	36·7
59·850			0			1·46	,,	52·1
56·638			3			,,	,,	63·3
54·573			7			,,	,,	70·5
49·463			2			,,	,,	88·4
39·845			0			,,	,,	18722·0
36·794			0			,,	,,	32·7
31·237			2			,,	,,	52·3
29·890			4			,,	,,	57·0
29·571			0			,,	,,	58·1
14·911			3			1·45	,,	18809·9
5292·279			4			,,	5·2	90·3
80·250			2			1·44	,,	18933·3
69·429			3			,,	,,	72·2
68·092			0			,,	,,	77·0
59·382			3			,,	,,	19008·4
51·549			2n			,,	,,	36·8
48·918			0			1·43	,,	46·3
37·918			1			,,	,,	86·4
37·284			5			,,	,,	88·7
30·752			4			,,	,,	19112·5
25·706			1			,,	,,	31·0
22·783			4			,,	,,	41·7
14·913			3			,,	,,	70·6
13·491			2			,,	,,	75·8
12·866			4			1·42	,,	78·1
11·637			4			,,	,,	82·6
07·099			3			,,	5·3	96·0
03·468			2			,,	,,	19212·7
5197·697			1			,,	,,	34·0
93·276			7			,,	,,	50·4
87·088			0			,,	,,	73·3
85·172			1			,,	,,	80·5
84·342			4			,,	,,	83·6
78·311			0			,,	,,	19306·0
77·396			3			,,	,,	09·4
76·110			6			,,	,,	14·2
74·883			0			1·41	,,	18·8
65·561			0			,,	,,	53·7
60·464			0n			,,	,,	72·8
57·814			5			,,	,,	82·8
57·224			2			,,	,,	85·0
55·691			5			,,	,,	90·7

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5145·110			2			1·41	5·3	19430·6
30·903			2			1·40	,,	84·5
20·824			1			,,	,,	19522·8
10·115			2			,,	5·4	63·6
5090·795			5			1·39	,,	19637·9
88·949			0			,,	,,	45·0
85·676			4			,,	,,	57·7
73·607			0			,,	,,	19704·4
64·475			4			,,	,,	40·0
57·576			2			1·38	,,	66·9
46·583			2			,,	,,	19810·0
28·492			2			,,	,,	81·3
25·692			1			1·37	5·5	92·2
12·538			0			,,	,,	19944·5
4997·919			1			,,	,,	20002·8
96·012			0			,,	,,	10·5
85·107			2			1·36	,,	54·2
77·969			4			,,	,,	83·0
66·511			2			,,	,,	20129·4
63·831			4			,,	,,	40·2
61·012			0			,,	,,	51·7
60·318			1			,,	,,	54·5
44·975			2			1·35	,,	20217·1
22·633			2			,,	5·6	20310·6
19·821			2			,,	,,	20·3
18·953			2			,,	,,	23·9
13·649			2			1·34	,,	45·9
08·744			2			,,	,,	66·2
4898·022			1			,,	,,	20410·8
88·045			0			,,	,,	52·5
65·922			4			1·33	,,	20545·5
61·808			0n			,,	5·7	62·8
61·497			2n			,,	,,	64·1
56·614			0			,,	,,	84·8
51·777			6			,,	,,	20605·3
44·145			6			,,	,,	37·8
42·556			4			,,	,,	44·5
33·627			0			1·32	,,	82·7
17·233			0			,,	,,	20753·1
13·678			1			,,	,,	68·4
10·645			6			,,	,,	81·5
03·393			0			1·31	,,	20812·9
01·517			1n			,,	,,	21·0
4798·829			4			,,	,,	32·7
94·364			0			,,	,,	52·1
91·640			0			,,	,,	64·0
91·164			3			,,	,,	66·0
77·304			2			,,	5·8	20926·5
71·687			2			,,	,,	51·1
70·938			3			,,	,,	54·4
55·717			4			1·30	,,	21021·5
50·007			0			,,	,,	46·8
45·276			6			,,	,,	67·8
31·333			1n			,,	,,	21129·9

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4724·483			2			1·29	5·8	21160·6
21·148			6			,,	,,	75·5
19·545			2			,,	,,	82·7
07·108			1n			,,	5·9	21238·6
04·230			5			,,	,,	51·6
4696·463			1			,,	,,	86·7
89·610			1			1·28	,,	21317·8
				4686·0	1n	,,	,,	34·
83·093		4683·15	1n	83·0	1n	,,	,,	47·4
				81·7	1n	,,	,,	54·
77·532		77·55	1n	77·6	1n	,,	,,	72·9
75·187		75·20	10	75·2	2	,,	,,	83·6
66·261			2			,,	,,	21424·5
43·337		43·35	3			1·27	,,	21530·3
39·526		39·53	2n	40·5	1n	,,	,,	48·0
34·017		34·05	1n			,,	6·0	73·5
26·105		26·12	1n			,,	,,	21610·4
				20·2	1n	,,	,,	38·
20·059		20·07	3			,,	,,	38·7
08·294		08·30	4	08·3	2n	1·26	,,	94·0
01·792		01·82	1			,,	,,	21724·6
4599·553		4599·6	1n			,,	,,	35·1
72·794		72·81	1	4572·7	1	1·25	,,	21862·4
				72·5	1	,,	,,	64·
71·466		71·48	2	71·6	1	,,	,,	68·8
70·489		70·51	1n			,,	,,	73·4
69·181	4569·184	69·19	6	69·3	2	,,	,,	79·7
68·538		68·55	1			,,	,,	82·8
65·373		65·37	3	65·3	1	,,	,,	98·0
				63·0	1	,,	6·1	21909·
61·062		61·08	3	61·0	1	,,	,,	18·8
58·897		58·90	3	58·9	1	,,	,,	29·0
57·343		57·35	2n	57·3	1n	,,	,,	36·5
51·828		51·83	4	51·8	1	,,	,,	63·1
		48·89	3	48·8	1	,,	,,	77·3
44·447		44·45	3	44·6	1	,,	,,	98·8
30·763		30·77	1	30·9	1	1·24	,,	22065·2
28·904	28·901	28·91	9	29·0b	4	,,	,,	74·3
				25·5	1	,,	,,	91·
				08·0	1n	,,	,,	22177·
06·815		06·83	1	06·8	1n	,,	,,	82·5
03·955	03·955	03·96	3	04·1	1	1·23	,,	96·6
4492·644	4492·643	4492·65	4	4492·7	5	,,	6·2	22252·4
84·015		84·00	2	84·0	1	,,	,,	95·3
				78·3	1n	,,	,,	22324·
				48·5	1b	1·22	,,	22473·
				43·5	1b	,,	,,	99·
33·495	33·489	33·50	3	33·6	1	,,	,,	22549·4
				26·6	1	1·21	6·3	84·
				26·3	1	,,	,,	86·
24·215	24·217	24·23	2	24·3	1	,,	,,	96·7
23·835	23·824	23·84	1			,,	,,	98·6
21·383		21·38	1n			,,	,,	22611·1
20·178		20·17	1n			,,	,,	17·2

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4410·449		4410·45	1n			1·21	6·3	22667·1
				4405·8	1n	,,	,,	91·
02·725	4402·716	02·74	1			,,	,,	22706·9
4388·224	4388·215	4388·24	2	4388·2	1	1·20	,,	82·0
80·097	80·082	80·11	8	80·1	1n	,,	,,	22824·2
				79·2	1	,,	,,	29·
				77·0	1n	,,	,,	40·
76·350	76·347	76·35	1			,,	,,	43·8
				76·2	1	,,	,,	45·
74·976	74·981	75·00	10r	74·9b	8	,,	,,	50·9
73·212	73·212	73·22	6			,,	,,	60·2
				72·5	2	,,	,,	64·
				64·0	1n	,,	6·4	22908·
62·393		62·40	1n			,,	,,	16·8
49·336	49·333	49·32	2			1·19	,,	85·6
45·629	45·626	45·62	3			,,	,,	23005·2
45·247	45·245	45·25	2	45·3	1	,,	,,	07·
42·608	42·604	42·60	4			,,	,,	21·3
				42·5	1	,,	,,	22·
				39·5	1n	,,	,,	38·
36·181	36·176	36·19	1			,,	,,	55·4
				28·8	1b	,,	,,	95·
25·584	25·578		1			,,	,,	23111·9
				23·2	1b	,,	,,	25·
				20·0	1n	,,	,,	42·
				17·3	1n	1·18	,,	56·
15·126	15·123	15·14	3	15·2	1	,,	,,	67·9
				13·6	1b	,,	,,	76·
				10·7	1	,,	,,	92·
08·982	08·988	08·99	2	09·0	1	,,	6·5	23200·8
				00·7	1n	,,	,,	45·5
4296·926	4296·931	4296·93	5			,,	,,	65·9
				4296·8	4	,,	,,	67·
88·883	88·807	88·89	10r	88·8b	8	,,	,,	23309·6
				84·6	1n	,,	,,	33·
				82·0	1b	,,	,,	47·
				79·3	1n	1·17	,,	62·
78·744	78·755	78·74	4	78·7	2	,,	,,	64·8
				78·2	1	,,	,,	68·
76·962	76·974	76·97	2	77·0	1	,,	,,	74·5
				76·5	1n	,,	,,	77·
				76·1	1n	,,	,,	79·
				74·8	1n	,,	,,	86·
73·578	73·581	73·59	4	73·5	2	,,	,,	93·1
				72·4	1	,,	,,	23400·
70·696		70·72	2	70·7	1	,,	,,	08·9
				69·7	1n	,,	,,	14·
				69·2	1	,,	,,	17·
				65·3	1n	,,	,,	39·
				64·5	1n	,,	,,	43·
				63·8	1n	,,	,,	47·
				62·3	1n	,,	,,	55·
	60·706			60·7	1 Fe	,,	,,	63·8
				60·1	1n	,,	,,	67·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				4259·7	1n	1·17	6·5	23469·
				59·3	1n	,,	,,	72·
4258·608	4258·617	4258·62	1n			,,	,,	75·3
				58·4	1n	,,	,,	76·
				56·6	1n	,,	,,	86·
				56·3	1	,,	,,	88·
				52·7	1n	,,	6·6	23508·
				49·1	1	,,	,,	28·
				48·0	1b	,,	,,	34·
				45·4	1n	,,	,,	48·
				44·7	2	,,	,,	52·
44·598	44·599	44·60	3			,,	,,	52·7
				32·7	1n	1·16	,,	23619·
				32·3	1n	,,	,,	21·
30·354	30·358	30·36	2	30·3	1	,,	,,	32·1
28·002			0			,,	,,	45·2
				21·5	1	,,	,,	82·
	21·362		1			,,	,,	82·4
				21·2	1	,,	,,	83·
				20·0	1n	,,	,,	90·
18·142	18·153	18·15	1	18·2	1	,,	,,	23700·5
11·306	11·304	11·26	20r	11·4b	10	,,	,,	39·1
06·770	06·777	06·75	3	06·7	2	,,	,,	64·6
				04·1	1n	1·15	,,	80·
4196·672	4196·661	4196·68	7	4196·6	6	,,	6·7	23821·7
				95·7	1b	,,	,,	27·
				82·7	1	,,	,,	23901·
77·780	77·803	77·80	2	77·8	2	,,	,,	29·4
				75·8	2	,,	,,	41·
				71·5	1n	,,	,,	65·
				66·9	1n	1·14	,,	92·
				66·2	1 Ir	,,	,,	96·
58·615	58·634	58·64	2			,,	,,	24039·7
				57·4	1	,,	,,	47·
54·495	54·521	54·52	4	54·5b	6	,,	,,	63·5
37·008	37·025	37·01	1	37·0	1	,,	6·8	24165·2
35·448	35·445	35·45	13r	35·4b	6	,,	,,	73·4
				33·9	1	,,	,,	83·
29·080	29·054	29·06	10r	29·0b	8	1·13	,,	24211·8
25·063	25·068	25·05	1	25·0	1	,,	,,	35·3
				22·7	1	,,	,,	49·
21·870	21·855	21·86	9r	21·7b	6	,,	,,	54·1
19·855	19·852	19·85	5	19·8	4	,,	,,	65·9
16·496	16·496	16·49	4	16·4	2	,,	,,	85·7
				13·6	1n	,,	,,	24303·
	07·665	07·65	4	07·5	2	,,	,,	38·0
4097·690	4097·692	4097·69	6	4097·7	6	,,	6·9	97·1
				93·0	1n	1·12	,,	24425·
				91·0	1	,,	,,	37·
88·646	88·651	88·64	2			,,	,,	51·1
87·950	87·948	87·94	2	88·0	2	,,	,,	55·3
				85·5	1	,,	,,	70·
				85·4	1	,,	,,	71·
84·442	84·450	84·45	2	84·5	1	,,	,,	76·2

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	1/λ −	
4082·942	4082·949	4082·99	10	4083·0b	8	1·12	6·9	24485·1
81·961	81·975	81·98	2	82·0	1	,,	,,	91·1
80·690	80·699	80·70	1	80·9	1	,,	,,	98·8
77·739	77·748	77·74	4	77·8	2	,,	,,	24516·5
				61·0	1b	,,	,,	24618·
				59·5	1b	,,	,,	27·
56·491	56·503	56·50	2	56·5	2	,,	,,	44·9
53·602	53·603	53·60	2	53·7	2	1·11	,,	62·5
49·188	49·200	49·17	2	49·2	2	,,	7·0	89·3
48·572	48·571	48·56	3	48·6	2	,,	,,	93·1
				43·6	1n	,,	,,	24723·
				43·0	1n	,,	,,	27·
				40·3	1b	,,	,,	44·
				34·0	1	,,	,,	82·
				28·6	1	,,	,,	24816·
26·089		26·09	1	26·2	1n	,,	,,	31·5
23·302	23·301	23·29	4	23·3	6	,,	,,	48·2
				20·3	1	,,	,,	67·
				17·1	1	,,	,,	87·
				05·5	1n	1·10	,,	24959·
				03·3	1n	,,	7·1	72·
3996·313	3996·307	3996·31	6	3996·2	8	,,	,,	25016·0
95·768	95·766	95·77	5	95·7	6	,,	,,	19·4
				86·6	1n	,,	,,	77·
84·555	84·556	84·56	5	84·5b	6	,,	,,	89·8
76·240				76·3	1	,,	,,	25142·3
				76·1	1	,,	,,	43·
75·472	75·465	75·48	5	75·3b	6	1·09	,,	47·1
				73·5	1n	,,	,,	60·
				69·3	1n	,,	,,	86·
68·320		68·33	2			,,	,,	92·4
64·688	64·688	64·68	3			,,	,,	25215·6
59·006	59·009	59·00	20r	59·0b	10bᵛ	,,	,,	57·8
58·313		58·31	4	58·3	4	,,	,,	56·2
53·214		53·20	1			,,	7·2	88·7
				50·6	1b	,,	,,	25305·
		44·10	2			,,	,,	47·1
42·862		42·88	5	42·9b	6	,,	,,	55·0
	42·059		8			,,	,,	60·2
				40·6	1	,,	,,	70·
				39·8	2	,,	,,	75·
				38·7	1	,,	,,	82·
		38·05	1	38·0	1	,,	,,	86·1
35·982	35·983	35·99	6	35·9b	4	1·08	,,	99·4
35·123	35·120	35·11	4	35·1	2	,,	,,	25405·0
34·384	34·368	34·39	15r	34·3c	8	,,	,,	09·8
				29·5	1n	,,	,,	41·
				26·6	1	,,	,,	60·
				26·2	1	,,	,,	63·
				25·1	1	,,	,,	70·
				24·7	1	,,	,,	72·
22·340	22·337	22·34	5	22·4	4	,,	,,	87·8
		16·55	1			,,	,,	25525·7
				15·8	1	,,	,,	30·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3914·3″	1	1·08	7·2	25540·
3913·657	°913·648	3913·64	4	13·7	1n	,,	,,	44·4
12·971	12·964	12·98	2	13·0	1	,,	,,	48·9
				12·6	1	,,	,,	51·
				11·7	1	,,	,,	57·
				11·2	1	,,	,,	60·
				10·6	1	,,	,,	64·
				10·0	1	,,	,,	68·
				08·6	1	,,	7·3	77·
				08·3	1	,,	,,	79·
				07·6	1	,,	,,	84·
				07·0	1n	,,	,,	88·
				06·2	1	,,	,,	93·
				05·5	1	,,	,,	98·
05·423		05·41	1			,,	,,	98·2
				05·1	1	,,	,,	25600·
				04·5	2	,,	,,	04·
04·362	04·359	04·35	2			,,	,,	05·2
				03·0	1	,,	,,	14·
		02·66	1			,,	,,	16·2
				02·3	1	,,	,,	19·
				02·1	1	,,	,,	20·
				01·5	1	,,	,,	24·
				01·1	1	,,	,,	26·
				00·2	1	,,	,,	32·
				3899·0	1	,,	,,	40·
				98·6	1	,,	,,	43·
		3898·13	2	98·1	1	,,	,,	46·0
				97·8	1	,,	,,	48·
				97·3	1	,,	,,	51·
				96·8	1	1·07	,,	55·
				96·1	1	,,	,,	59·
				94·8	1n	,,	,,	68·
				93·8	1n	,,	,,	75·
3891·953			0	92·0	1n	,,	,,	86·7
				90·5	1	,,	,,	96·
				89·6	1n	,,	,,	25702·
				89·1	1n	,,	,,	06·
88·475		88·48	2	88·5	2	,,	,,	09·7
				87·5	1	,,	,,	16·
	3886·470		3			,,	,,	23·0
				86·0	1n	,,	,,	26·
				84·3	1b	,,	,,	37·
				83·2	1b	,,	,,	45·
				82·4	1n	,,	,,	50·
				81·0	1	,,	,,	59·
				80·2	1	,,	,,	65·
				77·9	1	,,	,,	80·
77·470	77·482	77·47	4	77·4b	4	,,	,,	82·7
				76·6	1	,,	,,	88·
				74·8	1	,,	,,	25800·
72·534	72·532	72·57	3	72·5	2	,,	,,	15·5
				70·4b	2	,,	,,	30·
70·140	70·151	70·16	5	70·2	6	,,	,,	31·5

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3869·2	1	1·07	7·3	25838·
3865·291			1			,,	,,	63·9
				63·7	1	,,	,,	75·
56·663	3856·654	3856·62	20r	56·7b	10	1·06	,,	25922·0
56·167	56·165	56·15	4	56·3	2	,,	,,	25·2
		54·81	3	54·8	2	,,	,,	34·3
				53·5	1n	,,	,,	43·
				52·7	1n	,,	,,	49·
		49·14	2	49·2	2	,,	,,	72·5
		44·55	1			,,	,,	26003·5
				44·0	1b	,,	,,	07·
				41·3	1	,,	,,	26·
				40·6	1	,,	,,	30·
				40·3	1	,,	,,	32·
				38·9	1b	,,	,,	42·
34·893	34·895	34·89	3	35·0	2	,,	,,	69·1
34·016	34·020	34·03	15r	34·1b	6	,,	,,	75·0
33·733			0			,,	,,	76·9
		29·17	1			,,	,,	26108·0
28·623	28·615	28·61		28·7b	6	,,	,,	11·8
27·505			15r			,,	,,	19·4
			0	24·8	1	,,	,,	38·
22·397	22·399	22·43	15r	22·5b	6	,,	,,	54·2
		18·90	1			,,	,,	78·2
18·345	18·339	18·34	4	18·4b	8	,,	,,	82·1
17·990			0	18·0	1n	,,	7·4	84·4
17·524			0			,,	,,	87·6
16·611	16·611	16·62	4	16·7b	6	1·05	,,	93·8
15·169	15·166	15·18	3	15·2b	4	,,	,,	26203·7
12·599	12·603	12·61	3	12·7	1	,,	,,	21·4
				11·9	1	,,	,,	26·
09·655	09·648	09·65	3	09·7	2	,,	,,	41·7
06·920	06·908	06·91	4	06·9c	4	,,	,,	60·6
06·071	06·070	06·08	4	06·1b	4	,,	,,	66·4
3799·466	3799·461*	99·46	7r	3799·6	10	,,	,,	26312·1
				98·3	1	,,	,,	20·
				95·0	1	,,	,,	43·
93·366	93·364	93·40	4r	93·3b	8	,,	,,	54·4
		92·33	4	92·4	4	,,	,,	61·6
				91·6	1	,,	,,	67·
		90·58	1			,,	,,	73·8
				89·8	1	,,	,,	79·
88·633	88·624	88·64	6	88·7b	6	,,	,,	87·4
				86·0	2	,,	,,	26406·
				85·4	1n	,,	,,	10·
				81·0	1n	,,	,,	41·
				80·0	1n	,,	,,	48·
78·279	78·279	78·28	4	78·3b	4	,,	,,	59·7
				77·0	1	,,	,,	69·
75·864		75·85	2	76·0	2	1·04	,,	76·6
				72·8	1	,,	7·5	98·
71·779		71·77	2	71·8	2	,,	,,	26505·2
70·130	70·125	70·13	5	70·1b	2	,,	,,	16·8

* Distinct from Ru 3799·489.

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3768·8	1	1·04	7·5	26526·
				67·2	1	,,	,,	37·
3765·232	3765·227	3765·24	8r	65·2b	10	,,	,,	51·3
				60·9	1	,,	,,	82·
60·554	60·559	60·55	2	60·6	2	,,	,,	84·3
				59·6	1	,,	,,	91·
				57·3	1n	,,	,,	26607·
55·748	55·736	55·73	2	55·7	2	,,	,,	18·4
55·290			1			,,	,,	21·6
54·441	54·431	54·44	5			,,	,,	27·7
54·269	54·268	54·26	5	54·3b	6	,,	,,	28·8
				50·6	1	,,	,,	55·
48·383	48·362	48·37	6	48·4c	8	,,	,,	70·8
				46·1	1	,,	,,	87·
				45·7	1	,,	,,	90·
44·325	44·325	44·32	4	44·2b	8	,,	,,	99·6
37·448	37·421	37·43	4			1·03	,,	26700·
				37·3b	6	,,	,,	48·8
	36·295	36·00	4			,,	,,	50·
35·429	35·429	35·44	6	35·4b	8	,,	,,	58·0
						,,	,,	63·1
				35·0	1	,,	,,	66·
		34·34	1			,,	,,	71·0
				33·4	1n	,,	,,	78·
				31·6	1	,,	,,	90·7
				26·8	1	,,	7·6	26825·
25·091		25·10	2	25·1	1	,,	,,	37·4
				22·3	1n	,,	,,	58·
		20·91	1			,,	,,	67·6
				17·2	1	,,	,,	94·
				15·3	1	,,	,,	26908·
14·989	14·975	14·99	4	15·0	2	,,	,,	10·4
		13·98	1	14·0	1	,,	,,	17·7
13·593	13·575	13·60	3	13·6	4	,,	,,	20·4
13·156	13·172	13·18	4r	13·1c	8	,,	,,	23·6
	09·773		2	09·8	1	,,	,,	48·2
				08·6	1	,,	,,	57·
				07·1	1	,,	,,	68·
				05·2	1	,,	,,	81·
				04·5	1	,,	,,	87·
				02·7	1n	,,	,,	27000·
01·057	01·056	01·07	20r	01·1b	8	,,	,,	11·7
				00·3	1	,,	,,	17·
3699·461	3699·458	3699·46	2	3699·5b	2	,,	,,	23·4
98·758	98·742	98·76	5	98·7	4	,,	,,	28·5
98·415	98·410	98·40	3	98·4	4	,,	,,	31·0
		96·24	1			1·02	,,	46·9
95·674	95·669	95·65	5	95·7b	6	,,	,,	51·1
95·105	95·099	95·10	2	95·1	2	,,	,,	55·3
				94·3	1	,,	,,	61·
92·506	92·502	92·51	25r	92·5	10	,,	,,	74·3
				91·6	2	,,	,,	81·
91·481	91·477	91·50	2			,,	,,	81·7
90·872	90·853	90·88	8r	90·9b	8	,,	,,	86·3

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
				3688·7	1n	1·02	7·6	27102·
				88·0	1	,,	,,	07·
	3683·615		4			,,	7·7	39·6
				83·3	1n	,,	,,	42·
	83·030		2			,,	,,	43·9
3681·205	81·184	3681·19	6	81·2b	10	,,	,,	57·4
				80·3	1	,,	,,	64·
	79·353		2			,,	,,	71·0
				79·0	1	,,	,,	74·
				77·5	1b	,,	,,	85·
				75·9	1	,,	,,	97·
74·924	74·916	74·92	5	74·9	4	,,	,,	27203·8
	73·710		2			,,	,,	12·7
				73·5	1n	,,	,,	14·
				70·7	1b	,,	,,	35·
				69·2	1	,,	,,	46·
67·070	67·065	67·08	6	67·1	4	,,	,,	62·0
66·381	66·366	66·39	7	66·3b	8	,,	,,	67·2
				64·9	1	,,	,,	78·
62·027	62·018	62·02	3	62·0b	4	,,	,,	99·6
61·760	61·748	61·77	2			,,	,,	27301·6
		61·55	1			,,	,,	03·1
58·148	58·135	58·15	15r	58·2b	10	,,	,,	28·6
	56·994		2			1·01	,,	37·2
55·044	55·026	55·04	8	55·0c	4	,,	,,	51·8
	54·569		1			,,	,,	55·3
		53·64	1			,,	,,	62·3
51·516	51·505	51·53	2			,,	,,	78·2
				49·8	1	,,	,,	91·
				49·0	1n	,,	,,	97·
		48·51	1			,,	,,	27400·7
44·363			0			,,	,,	31·9
				43·8	1b	,,	,,	36·
43·301			0			,,	,,	39·9
		42·83	1	42·8	1b	,,	,,	43·5
				42·2	1n	,,	,,	48·
				41·3	2	,,	,,	55·
39·684	39·662	39·69	6	39·7	4	,,	,,	67·3
				37·1	1	,,	7·8	87·
				35·9	1n	,,	,,	96·
				33·8	1	,,	,,	27512·
				33·0	1	,,	,,	18·
				32·3	1	,,	,,	23·
				30·5	1	,,	,,	37·
				29·7	1b	,,	,,	43·
27·958	27·957	27·95	4	28·0	2	,,	,,	55·9
27·342	27·334	27·30	4	27·3	1	,,	,,	60·7
26·759	26·744	26·75	7	26·7b	10	,,	,,	65·1
				25·0	1	,,	,,	78·
				24·5	1	,,	,,	82·
				23·2	1	,,	,,	92·
				23·0	1	,,	,,	94·
				22·2	1	,,	,,	27600·
20·621	20·605	20·61	5	20·6	4	,,	,,	11·8

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3619·1	1	1·01	7·8	27623·
				16·6	1n	1·00	,,	42·
				15·2b	1	,,	,,	53·
3614·934	3614·931	3614·93	4			,,	,,	55·2
				14·8	8	,,	,,	56·
14·674		14·67	1			,,	,,	57·2
14·099			1			,,	,,	61·6
				13·9	1n	,,	,,	63·
12·621	12·618	12·62	6r			,,	,,	72·9
				12·5	8	,,	,,	74·
		10·93	1n			,,	,,	85·9
				09·0	1n	,,	,,	27701·
				08·5	1	,,	,,	05·
08·246	08·243	08·25	4	08·2	2	,,	,,	06·5
				07·9	1	,,	,,	09·
06·029	06·019	06·05	6			,,	,,	23·5
				05·8c	6	,,	,,	25·
				03·0	1n	,,	,,	47·
	02·182		2			,,	,,	53·1
00·911		00·90	4			,,	,,	63·0
				00·6	1n	,,	,,	65·
3598·057	3598·051	3598·05	4	3598·0	2	,,	,,	85·0
97·300	97·294	97·31	12r	97·3b	8	,,	,,	90·8
96·343		96·32	4r	96·3b	10	,,	,,	98·3
96·183	96·185		4			,,	,,	99·4
				95·5	1b	,,	,,	27805·
				94·8	1	,,	7·9	10·
94·054		94·07	0			,,	,,	15·8
93·685		93·70	3	93·7	2	,,	,,	18·7
				93·0	1	,,	,,	24·
90·688	90·678	90·65	1	90·6	2	,,	,,	42·0
				85·8	2	,,	,,	80·
				85·0	1	,,	,,	86·
	83·683	83·67	4	83·6b	4	,,	,,	96·4
	83·252	83·24	20r			,,	,,	99·8
				83·1	6	,,	,,	27901·
				80·8	1	,,	,,	19·
		80·41	1	80·5	1	,,	,,	21·9
				79·7	1n	,,	,,	27·
				78·6	1	,,	,,	36·
				77·0	1	0·99	,,	48·
				76·6	1	,,	,,	52·
				76·2″	1	,,	,,	55·
				75·7	1	,,	,,	59·
				75·4	1	,,	,,	61·
				74·0	1	,,	,,	72·
				73·4	1	,,	,,	77·
				72·5	1	,,	,,	84·
				72·1	1	,,	,,	87·
				71·8	1	,,	,,	89·
				71·0	2	,,	,,	95·
	70·333		10	70·3	8	,,	,,	28000·7
				69·2	1	,,	,,	10·
				68·9	1	,,	,,	12·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				3568·6	1	0·99	7·9	28014·
				68·3	1	,,	,,	17·
				67·1	1n	,,	,,	26·
				66·3	1	,,	,,	32·
3564·290	3564·282	3564·31	3	64·2	2	,,	,,	48·2
				62·2	2	,,	,,	58·
				63·0	1n	,,	,,	65·
				61·8	1n	,,	,,	68·
		60·53	1			,,	,,	77·8
				60·3	1	,,	,,	80·
				60·1	1	,,	,,	81·
				59·2	1	,,	,,	88·
				59·0	1	,,	,,	90·
				58·6	1	,,	,,	93·
				58·0″	1	,,	,,	98·
				57·5	1	,,	,,	28102·
				57·2	1	,,	,,	04·
				56·8	1n	,,	,,	07·
				53·9	1	,,	,,	30·
				53·6	1	,,	,,	33·
				53·1	1	,,	,,	37·
				52·8	1	,,	,,	39·
				51·8	1	,,	8·0	47·
				50·4	1b	,,	,,	58·
50·165	50·145	50·15	1			,,	,,	59·8
				50·0	1	,,	,,	61·
49·681	49·689	49·70	5	49·6c	10	,,	,,	63·5
44·122	44·097	44·13	5			,,	,,	28207·8
				43·9	8	,,	,,	09·
42·068	42·065	42·05	4			,,	,,	24·2
				41·9	4	,,	,,	25·
38·409	38·391	38·41	4			,,	,,	53·3
38·269	38·293	38·27	3	38·2b	8	,,	,,	54·4
				37·3	1	0·98	,,	62·
				36·6	1	,,	,,	68·
				36·4	1	,,	,,	69·
				34·3	1n	,,	,,	86·
				32 3	1	,,	,,	28302·
	30·536		2	30·6	1	,,	,,	16·3
28·183	28·177	28·18	15r	28·1b	10	,,	,,	35·2
25·805	25·808	25·80	2			,,	,,	54·3
				25·7	6	,,	,,	55·
				22·5	2	,,	,,	81·
				20·9	1	,,	,,	94·
19·690	19·692	19·67	2	19·6	2	,,	,,	28403·6
				17·7	1	,,	,,	20·
				17·3	1	,,	,,	23·
				16·8	1	,,	,,	27·
				14·8	1	,,	,,	43·
				13·7	4	,,	,,	52·
13·258	13·258	13·25	4	13·2	4	,,	,,	55·6
11·942	11·940	11·94	4	11·9	2	,,	,,	66·3
11·696	11·691	11·69	3	11·6	2	,,	,,	68·3
				10·7	1	,,	8·1	76·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3509·444			3			0·98	8·1	28486·4
08·754		3508·65	1			,,	,,	92·5
07·471	3507·466	07·48	8r	3507·4b	8	,,	,,	28502·5
05·559	05·558	05·55	4	05·5	2	,,	,,	18·0
02·686	02·674	02·67	15r	02·6a	10	,,	,,	41·5
		00·70	1	00·7	1	,,	,,	57·6
				3499·3	1	,,	,,	69·
3498·887	3498·878	3498·88	15	98·8b	8	0·97	,,	72·4
				96·6	1	,,	,,	91·
				96·0	1	,,	,,	96·
94·585	94·591	94·58	5	94·5	2	,,	,,	28607·6
91·365	91·353	91·35	3			,,	,,	34·1
91·216	91·218	91·21	3	91·2″	2	,,	,,	35·2
				90·6	1	,,	,,	40·
				90·3	1	,,	,,	43·
		89·81	1			,,	,,	46·8
87·621	87·609	87·61	3			,,	,,	64·8
				87·5	1	,,	,,	66·
87·366	87·363	87·36	3			,,	,,	66·9
				87·2	1	,,	,,	68·
85·031			2			,,	,,	86·0
84·186	84·184	84·19	4			,,	,,	93·0
				84·0	4	,,	,,	95·
		83·20	0			,,	,,	28701·1
		81·33	2			,,	,,	16·5
80·658			0			,,	,,	22·1
79·064	79·053	79·07	10r	79·0b	2	,,	,,	35·3
78·646	78·640	78·65	2			,,	,,	38·7
		77·96	1	77·9b	8	,,	,,	44·4
77·354			1			,,	,,	49·4
74·939	74·920	74·95	10r	74·9a	8	,,	,,	69·4
		73·93	1			,,	,,	77·7
				73·8	1	,,	,,	79·
72·994			0			,,	,,	85·5
72·402	72·393	72·40	5	72·3	4	,,	,,	90·4
		71·46	2			,,	,,	98·2
70·817	70·805	70·82	10r			,,	8·2	28803·5
				70·6b	8	,,	,,	05·
70·515			1			,,	,,	06·0
69·774	69·770	69·80	6	69·7	5 Ni	,,	,,	12·0
69·355			0			,,	,,	15·6
				64·9	1	,,	,,	53·
62·191	62·184	62·19	12r	62·2a	8	,,	,,	75·3
59·375		59·36	3	59·3	1	,,	,,	98·7
58·815			0			0·96	,,	28903·4
58·070	58·072	58·07	3	58·1	4	,,	,,	09·7
57·219	57·216	57·21	5	57·2	4	,,	,,	16·8
56·284			0			,,	,,	24·6
55·595	55·571	55·57	4	55·5	1	,,	,,	30·5
55·369	55·365	55·36	4	55·4	4	,,	,,	32·3
54·617			0			,,	,,	38·6
				52·7	2	,,	,,	55·
51·294	51·298	51·30	4			,,	,,	66·4

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: 1/λ −	Oscillation Frequency in Vacuo
3450·437	3450·435	3450·47	5	3450·4	1	0·96	8·2	28973·5
48·715	48·723	48·72	5	48·7	2	,,	,,	88·1
47·897	47·883	47·89	6	47·8	2	,,	,,	95·0
				46·7	1	,,	,,	29005·
46·202			0			,,	,,	09·2
				45·4	1	,,	,,	16·
				43·1	1	,,	,,	35·
43·001			2			,,	,,	36·2
		42·87	1			,,	,,	37·3
42·781	42·775	42·79	4	42·8	2	,,	,,	38·0
42·243			0			,,	,,	42·6
40·675	40·671	40·69	4	40·6b	6	,,	,,	55·8
35·037	35·039	35·03	15r	35·0b	10	,,	,,	29103·6
				33·7	1 Ni	,,	,,	15·
32·234	32·238	32·24	2	32·3	1	,,	8·3	27·2
				31·0	1	,,	,,	38·
28·559		28·52	2			,,	,,	58·6
				28·2	1n	,,	,,	62·
24·532	24·532	24·49	6	24·5	4	,,	,,	92·9
23·699			0			,,	,,	99·9
22·430	22·434	22·43	3	22·4	1	,,	,,	29210·7
				21·3	8	,,	,,	20·
20·307	20·312	20·32	4	20·3	2	,,	,,	28·8
				18·1	1	,,	,,	48·
16·901			0			0·95	,,	58·0
15·824			0			,,	,,	67·2
				15·2	2	,,	,,	73·
12·425	12·417	12·43	6	12·4b	8	,,	,,	96·4
10·625			1			,,	,,	29311·8
10·074			0			,,	,,	16·6
08·990			0	09·0	1	,,	,,	25·9
07·884	07·883	07·87	2	08·0	1	,,	,,	35·5
07·387		07·38	2	07·4	1 Ni	,,	,,	39·7
06·690	06·694	06·70	5	06·7	4	,,	,,	45·7
04·021		04·03	2n	04·0	1n	,,	,,	68·7
03·247			0			,,	,,	75·4
				02·2	1	,,	,,	84·
01·109		01·11	3	01·2	1	,,	,,	93·9
				00·3	1	,,	,,	29401·
3399·823	3399·839	3399·82	7	3399·9b	4	,,	,,	05·0
96·956	96·960	96·95	15r	97·0b	10	,,	,,	29·8
				95·6	2	,,	8·4	41·
95·014	95·040	95·01	3			,,	,,	46·5
				92·8	1	,,	,,	66·
92·230		92·24	1			,,	,,	70·7
91·935	91·927	91·92	2	92·0	1	,,	,,	72·7
91·847		91·85	2			,,	,,	73·4
90·608			1n			,,	,,	84·8
				89·5″	1	,,	,,	94·
89·340	89·361	89·34	3			,,	,,	95·8
87·960			0			,,	,,	29507·9
				87·3	1	,,	,,	14·
87·174		87·16	2			,,	,,	14·8
				86·3	1	,,	,,	22·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3385·919	3385·924	3385·92	6	3386·0	4	0·95	8·4	29525·7
				82·6	1	,,	,,	55·
				81·7	2	,,	,,	63·
81·578	81·589	81·60	4			,,	,,	63·5
81·208			0			,,	,,	66·8
				81·0	1	,,	,,	69·
80·775		80·80	4			,,	,,	70·6
				78·7	1	,,	,,	89·
77·850	77·856	77·81	4	77·8	2	0·94	,,	96·3
77·742			2			,,	,,	97·2
77·275	77·282	77·28	5	77·2	4	,,	,,	29601·2
				76·5	1	,,	,,	08·
76·017			0			,,	,,	12·3
75·735			0n			,,	,,	14·8
73·879			0			,,	,,	31·1
72·930			0			,,	,,	39·4
72·672	72·668	72·68	2			,,	,,	41·7
72·379			7	72·4c	2	,,	,,	44·2
				71·6	1	,,	,,	51·
				71·3	1	,,	,,	54·
				70·9	1	,,	,,	57·
				70·6	1	,,	,,	60·
				70·2	1	,,	,,	63·
69·824		69·82	5	69·8	2	,,	,,	66·7
68·914	68·918	68·91	3			,,	,,	74·8
				68·8	1	,,	,,	76·
68·518		68·52	6	68·5	6	,,	,,	78·2
				66·9	1n	,,	,,	93·
65·650			0			,,	,,	29703·5
65·138			0	65·1	1	,,	,,	08·1
64·281			0	64·3	1	,,	,,	15·6
				63·7	1	,,	,,	21·
63·382			0			,,	,,	23·6
62·321	62·330	62·33	5	62·4	2	,,	,,	32·9
60·952	60·947	60·95	8	61·0	6	,,	8·5	45·0
60·043	60·038	60·04	6	60·0	4	,,	,,	53·0
58·962			0			,,	,,	62·6
57·980		58·00	2			,,	,,	71·4
57·560			0			,,	,,	75·0
56·670			1	56·7	1	,,	,,	82·9
				56·3	2	,,	,,	86·
				56·0	1	,,	,,	89·
				55·5	1	,,	,,	93·
54·853		54·85	4			,,	,,	99·1
				54·7	1	,,	,,	29800·
				54·5	1	,,	,,	02·
				54·1	1	,,	,,	06·
53·834		53·84	2			,,	,,	08·1
				53·7	1	,,	,,	09·
				53·6	1	,,	,,	10·
				53·2	1	,,	,,	14·
				52·8	1	,,	,,	17·
52·510		52·52	2			,,	,,	19·9
				52·3	1	,,	,,	22·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
				3352·0	1	0·94	8·5	29824·
				51·6	1	,,	,,	28·
				51·2	1	,,	,,	31·5
				51·1	1	,,	,,	32·5
				50·7	1	,,	,,	36·
				50·5	1	,,	,,	38·
				50·1	1	,,	,,	41·
				49·8	1	,,	,,	44·
				49·6	1	,,	,,	46·
				49·1	1	,,	,,	50·
				49·0	1	,,	,,	51·
				48·4	1	,,	,,	57·
				48·1	1	,,	,,	59·
				47·8	1	,,	,,	62·
3347·660			0			,,	,,	63·3
47·437			1	47·1	1	,,	,,	65·1
				46·9	1	,,	,,	70·
				46·7	1	,,	,,	72·
				46·2	1n	,,	,,	76·
	3346·071		1	46·1	1	,,	,,	77·3
	45·707		4			,,	,,	80·5
	45·156		10			,,	,,	85·5
				44·5	2	,,	,,	91·
44·337	44·340	3344·34	5			,,	,,	92·8
43·573		43·55	2			,,	,,	99·7
				43·2	2	,,	,,	29903·
43·036	43·039	43·05	5			,,	,,	04·4
				42·6	1	,,	,,	08·
				42·0	1	,,	,,	14·
				41·2	1	,,	,,	21·
40·987			0			,,	,,	22·8
				40·8	1n	,,	,,	24·
38·672	38·687	38·69	7	38·7	4	0·93	,,	43·4
36·842		36·85	0	36·9	4	,,	,,	59·9
35·328			0			,,	,,	73·6
32·648		32·66	1			,,	,,	97·6
31·393	31·381	31·42	4	31·4	2	,,	,,	30008·9
31·233	31·230	31·26	4			,,	,,	10·3
				26·0	1	,,	,,	58·
23·232	23·228	23·24	6r	23·3b	8	,,	8·6	82·6
				20·0	1	,,	,,	30112·
				18·5	1	,,	,,	25·
16·670			0			,,	,,	42·1
14·665		14·67	2	14·7	1n	,,	,,	60·3
				13·2	1n	,,	,,	74·
				10·7	1n	,,	,,	96·
09·663		09·67	2	09·7	1n	,,	,,	30205·9
				08·2	1	,,	,,	19·
08·067		08·06	3			,,	,,	20·6
07·474		07·47	0	07·5c	4	,,	,,	26·0
07·091		07·10	1			,,	,,	29·4
				05·5	1	,,	,,	44·
05·298		05·30	4	05·3	1	,,	,,	45·8
04·258		04·25	2	04·2	1	,,	,,	55·4

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3303·872			0			0·93	8·6	30258·9
03·474		3303·49	0			,,	,,	62·5
	3303·068					,,	,,	66·3
	02·712		4	3302·7	1	,,	,,	69·5
		02·49	5			,,	,,	71·6
01·820		01·80	0			,,	,,	77·8
				01·5	1	,,	,,	81·
		01·40				,,	,,	81·6
00·604	00·593	00·56	4	00·5	1	,,	,,	89·0
00·479			4			,,	,,	90·0
00·133			0			,,	,,	93·2
3299·066		3299·06	2			0·92	,,	30303·0
				3298·5	1	,,	,,	08·
				98·3	1	,,	,,	10·
97·667			0			,,	,,	15·9
97·409		97·41	2	97·5	1	,,	,,	18·2
96·847	3296·842	96·86	4	96·8	2	,,	,,	23·4
				95·7	1	,,	,,	34·
94·843			0			,,	,,	41·9
94·400	94·404	94·42	5	94·5	4	,,	,,	45·9
				93·8	1	,,	,,	51·
93·533			0			,,	,,	53·9
93·012			0			,,	,,	58·7
				92·9	1n	,,	,,	60·
92·531			0			,,	,,	63·2
				92·3	1n	,,	,,	65·
				91·6	1	,,	,,	72·
				89·9	2	,,	,,	87·
89·739	89·750	89·73	5			,,	,,	88·9
				89·4	4	,,	,,	92·
89·274	89·266	89·26	5			,,	,,	93·3
88·159		88·16	2			,,	8·7	30403·4
				86·7	1	,,	,,	17·
86·520		86·54	4			,,	,,	18·5
85·964		85·99	2			,,	,,	23·6
84·151			0			,,	,,	40·6
83·705	83·695	83·71	4r	83·7b	6	,,	,,	44·7
82·932			0			,,	,,	52·0
	82·455		5	82·0	4	,,	,,	56·3
81·827	81·822	81·83	4			,,	,,	62·1
				80·8a	8	,,	,,	72·
80·680	80·664	80·68	2r			,,	,,	72·8
78·620		78·60	2			,,	,,	92·0
				77·0″	1	,,	,,	30507·
76·122		76·11	4			,,	,,	15·2
				75·1	1	,,	,,	25·
74·908		74·90	4			,,	,,	26·5
				74·3	2	,,	,,	32·
		73·47	1			,,	,,	39·9
				73·2	1	,,	,,	42·
				71·9	4	,,	,,	54·
71·748	71·736	71·75	8			,,	,,	56·0
70·702		70·72	3	70·7b	1	,,	,,	65·7
				69·9	1	,,	,,	73·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
				3268·7	2	0·92	8·7	30584·
3268·597		3268·62	5			,,	,,	85·4
				67·7	6	,,	,,	94·
67·605		67·62	1			,,	,,	94·7
				66·7b	1	,,	,,	30603·
66·511			1			,,	,,	05·0
				65·5	2	,,	,,	14·
				64·6	2	,,	,,	23·
64·313			0			,,	,,	25·6
63·924		63·95	2			,,	,,	29·1
				63·4b	6	,,	,,	34·
63·280	3263·268	63·30	8			,,	,,	35·3
				62·3	1	,,	,,	45·
	61·175		2	61·2	1b	,,	,,	55·1
60·938		60·97	2n			,,	,,	57·2
59·994			0			0·91	,,	66·2
58·352			0			,,	,,	81·7
				57·2	1n	,,	,,	93·
				56·6	1n	,,	,,	98·
				55·3	1	,,	,,	30710·
55·104		55·10	4			,,	,,	12·3
				54·8	1	,,	,,	15·
				54·2	1	,,	,,	21·
				53·7	1n	,,	,,	26·
53·457		53·47	2			,,	,,	27·8
				51·2	1n	,,	8·8	49·
				50·4	1n	,,	,,	57·
50·151		50·16	2			,,	,,	58·9
				49·6	1n	,,	,,	64·
		49·30	1			,,	,,	67·1
				47·2	1	,,	,,	87·
				45·1	1b	,,	,,	30807·
				44·0	1	,,	,,	17·
				43·5	1	,,	,,	22·
42·820		42·81	1			,,	,,	28·6
42·111			0			,,	,,	35·3
				41·8	1	,,	,,	38·
41·602			0			,,	,,	40·1
40·998			0			,,	,,	45·9
				40·7	2	,,	,,	49·
40·644			0			,,	,,	49·3
				39·3	2	,,	,,	62·
				38·6	1n	,,	,,	69·
				37·9	2	,,	,,	75·
37·781	37·777	37·80	4			,,	,,	76·5
				37·5	1n	,,	,,	79·
				36·3	1	,,	,,	91·
				36·0	1	,,	,,	94·
35·910		35·92	2			,,	,,	94·3
34·656			0			,,	,,	30906·4
				34·3	1	,,	,,	10·
33·440		33·45	0	33·6	4	,,	,,	18·0
32·627		32·65	4	32·7	1	,,	,,	25·7
				32·3	1	,,	,,	29·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
				3231·3	4	0·91	8·8	30938·
				29·5	1	,,	,,	56·
				29·0	1	,,	,,	61·
				25·4	1	,,	,,	95·
				24·7	2	,,	,,	31002·
3221·589			0	21·5	1	,,	,,	31·8
21·422			1			,,	,,	33·4
21·193			0			,,	,,	35·6
				21·0	2	,,	,,	37·
20·893			2			,,	,,	38·5
18·655			0			0·90	,,	60·1
				18·5	2	,,	,,	62·
		3218·40	3			,,	,,	62·5
18·009		18·00	4	18·1	2	,,	,,	66·3
				17·5	1	,,	,,	71·
				17·0	1	,,	,,	76·
				16·5	1n	,,	,,	81·
				15·1	1	,,	8·9	94·
14·984		15·00	4			,,	,,	95·4
14·628			0	14·6	1	,,	,,	98·9
14·440	3214·440	14·44	4			,,	,,	31100·7
				13·8	1	,,	,,	07·
				13·1	2	,,	,,	14·
12·667			0			,,	,,	17·9
				11·7	1	,,	,,	27·
11·504		11·52	3			,,	,,	29·1
				10·7	1n	,,	,,	37·
				09·6	1n	,,	,,	48·
07·390		07·41	2	07·4	6	,,	,,	69·0
06·202		06·21	4	06·3	1	,,	,,	80·6
				05·3	1n	,,	,,	89·
				02·0	1	,,	,,	31222·
				01·7	1n	,,	,,	25·
3199·979		3199·99	1			,,	,,	41·2
97·257	3197·248	97·26	4	3197·2	4	,,	,,	67·9
94·671	94·660	94·69	4	94·6	1	,,	,,	93·2
93·963		93·96	2	94·0	1	,,	,,	31300·2
93·633			1			,,	,,	03·4
92·336			0			,,	,,	16·1
92·112			0			,,	,,	18·3
91·313	91·305	91·33	6			,,	,,	26·1
				91·2b	4	,,	,,	27·
90·466		90·49	3	90·5	1	,,	,,	34·4
				90·1	1	,,	,,	38·
89·162	89·164	89·16	5	89·2	2	,,	,,	47·3
				88·7	4	,,	,,	52·
88·408		88·41	1			,,	,,	54·7
87·998		88·00	1	88·0b	6	,,	,,	58·7
87·740			0			,,	,,	61·3
87·265			0			,,	,,	66·0
85·702	85·710	85·72	5	85·6	2	,,	,,	81·3
				84·7	1n	,,	,,	82·
84·485			0			,,	,,	91·
83·558			0			,,	,,	31402·5

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
3183·012			0			0·90	8·9	31407·9
82·519			0			0·89	,,	12·8
81·330		3181·38	3	3181·3	1	,,	,,	24·2
				80·5	1	,,	9·0	33·
79·833	3179·843	79·84	5	80·0	2	,,	,,	39·2
78·517		78·51	4	78·6	1	,,	,,	52·2
				77·7	1	,,	,,	60·
				77·3	1	,,	,,	64·
77·201		77·20	4			,,	,,	65·2
77·020			0			,,	,,	67·0
76·666			0			,,	,,	70·6
				76·3	1	,,	,,	74·
				74·6	4	,,	,,	91·
				73·7	2	,,	,,	31500·
72·392		72·40	4	72·4	1	,,	,,	12·9
71·625		71·65	2	71·5	1n	,,	,,	20·4
70·379			0			,,	,,	33·0
				69·0	1	,,	,,	47·
67·072		67·07	0	67·1	2	,,	,,	66·5
				66·4	1	,,	,,	73·
				64·3	2	,,	,,	94·
63·551		63·55	1			,,	,,	31601·1
		62·84	0			,,	,,	08·1
62·608			0			,,	,,	10·5
				62·5	2	,,	,,	12·
62·388		62·40	1			,,	,,	12·6
59·354		59·35	2	59·3b	8	,,	,,	43·1
59·001			2			,,	,,	56·5
58·063		58·06	2	58·0	1n	,,	,,	56·0
	55·890	55·90		55·8	2	,,	,,	77·7
55·489			6			,,	,,	81·8
54·453			0			,,	,,	92·2
				53·7	2	,,	,,	31700·
52·724	52·719	52·73	6			,,	,,	09·6
				52·6	2	,,	,,	11·
		51·50	4	51·5	2	,,	,,	21 9
				50·7	1	,,	,,	30·
50·385		50·40	4	50·3	1	,,	,,	33·1
49·978			0	49·9	2	,,	,,	37·2
48·350			1			,,	,,	53·7
				48·0″	1n	,,	,,	57·
47·736		47·74	4			,,	,,	59·8
47·274			0	47·2	1n	,,	,,	64·5
46·327			0			,,	9·1	74·0
45·734		45·71	2n	45·7	1	,,	,,	80·1
45·518			1			,,	,,	82·2
41·314			0	41·3b	4	0·88	,,	31824·7
40·963			0			,,	,,	28·3
40·549			1			,,	,,	32·5
				40·4	1	,,	,,	34·
40·355			0			,,	,,	34·4
				38·7	1n	,,	,,	51·
38·506		38·50	1			,,	,,	53·2

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3137·825	3137·824	3137·83	5			0·88	9·1	31860·1
				3137·6	1	,,	,,	62·
37·450		37·45	4			,,	,,	63·9
35·590		35·59	2n			,,	,,	82·8
34·710			0			,,	,,	91·8
34·047			1			,,	,,	98·5
30·918		30·91	4	31·0	2	,,	,,	31930·5
				30·0	1n	,,	,,	40·
				29·2	1n	,,	,,	48·
				28·5	1b	,,	,,	55·
26·990		27·00	2			,,	,,	70·5
				26·2	1	,,	,,	79·
25·000			0			,,	,,	90·9
				24·6	1n	,,	,,	95·
24·508		24·50	2			,,	,,	96·0
23·818	23·814	23·81	6	23·8	4	,,	,,	32003·1
				23·1	1	,,	,,	10·
21·879	21·873	21·89	6			,,	,,	23·0
21·381			0			,,	,,	28·0
				21·2	2	,,	,,	30·
20·714			0			,,	,,	34·8
				20·0	1	,,	,,	42·
19·846			0			,,	,,	43·8
				18·2	4	,,	,,	61·
				17·7	1	,,	,,	66·
				16·6	1n	,,	,,	77·
				15·2	2	,,	,,	92·
15·027	15·026	15·02	5			,,	,,	93·4
				12·4	1b	,,	9·2	32120·
				10·6	1n	,,	,,	39·
				09·0	2	,,	,,	55·
08·405		08·40	2			,,	,,	61·7
				06·1	1n	,,	,,	86·
05·756			4			,,	,,	89·1
05·110		05·11	4	05·2	1	,,	,,	95·8
				03·5	2	,,	,,	32212·
02·634		02·65	4	02·7	1	,,	,,	21·4
	00·556			00·6	1	0·87	,,	43·
	00·407		2			,,	,,	43·1
			2			,,	,,	44·6
3099·567			0			,,	,,	53·4
		3097·06	2n	3097·0	4	,,	,,	79·5
96·834			1			,,	,,	81·8
96·722			0			,,	,,	83·0
				95·6	1n	,,	,,	95·
94·691		94·69	2			,,	,,	32304·2
				93·7	6	,,	,,	15·
93·592		93·58	0			,,	,,	15·7
				92·5	2	,,	,,	27·
91·840			0			,,	,,	34·0
				90·8	4	,,	,,	45·
90·506		90·52	2			,,	,,	47·9
89·775			0			,,	,,	55·6
89·480			0			,,	,,	58·7

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3088·428		3088·42	2			0·87	9·2	32369·8
				3087·7	1	,,	,,	77·
87·534		87·52	4			,,	,,	79·2
87·180			0			,,	,,	82·8
				86·0	1n	,,	,,	95·
85·790		85·78	2			,,	,,	97·5
84·078	3084·081	84·10	4	84·2	4	,,	,,	32415·3
				83·5	1	,,	9·3	21·
81·714			0	81·8	2	,,	,,	40·2
80·449			0			,,	,,	53·5
78·905			0			,,	,,	69·8
				78·5	1n	,,	,,	74·
				77·0	1	,,	,,	90·
76·736		76·75	2			,,	,,	92·6
	76·006		6			,,	,,	32500·4
				75·8	1	,,	,,	03·
74·806		74·82	2			,,	,,	13·0
				74·4	1	,,	,,	17·
				74·0	1	,,	,,	22·
73·550			0			,,	,,	26·4
				72·4	1n	,,	,,	39·
71·716			1			,,	,,	45·8
				71·3	1	,,	,,	50·
71·134		71·15	3			,,	,,	51·9
70·467			1			,,	,,	59·0
				69·9	1	,,	,,	65·
69·034			2			,,	,,	74·2
67·395		67·42	6	67·5	2	,,	,,	92·
66·475			0			,,	,,	32601·4
66·333			0			,,	,,	02·9
65·800			0			,,	,,	08·6
				64·5	1n	,,	,,	22·
				63·9	1n	,,	,,	29·
63·700			1			,,	,,	31·0
62·544			0	62·5	4	0·86	,,	43·3
61·782		61·80	2			,,	,,	51·3
60·001			0			,,	,,	70·4
				59·9	2	,,	,,	72·
59·473		59·47	2			,,	,,	76·1
58·974			1			,,	,,	81·4
				58·2	1	,,	,,	90·
57·996		58·01	4			,,	,,	91·8
				57·5	1	,,	,,	97·
56·452			0			,,	,,	32708·4
55·755		55·76	0	55·8	6	,,	,,	16·
54·980			0			,,	,,	24·1
				54·2	1n	,,	9·4	32·
53·988		54·01	2			,,	,,	34·5
				52·7	1	,,	,,	48·
51·780		51·83	2			,,	,,	58·1
50·842		50·92	2n			,,	,,	68·0
50·050			0			,,	,,	76·9
49·919			0			,,	,,	78·3
				4 ·6	1	,,	,,	82·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3049·334		3049·35	2			0·86	9·4	32784·6
				3049·1	6	,,	,,	87·
49·003		49·00	0			,,	,,	88·2
48·095		48·10	2			,,	,,	97·9
47·440		47·45	0			,,	,,	32805·0
		47·26	1	47·3c	6	,,	,,	07·0
46·871		46·87	4			,,	,,	11·1
46·304		46·30	2	46·3	1	,,	,,	17·3
				46·0	1	,,	,,	21·
45·887		45·90	3			,,	,,	21·7
43·586			0			,,	,,	46·6
				42·9	2	,,	,,	54·
				41·8	1n	,,	,,	66·
				40·6	1n	,,	,,	79·
38·583			2n	38·6	1	,,	,,	32900·7
				37·6	2	,,	,,	11·
36·483			0			,,	,,	23·4
		35·15	1	35·2	4	,,	,,	37·9
34·474			0			,,	,,	45·2
				34·3	1n	,,	,,	47·
				33·0	1n	,,	,,	61·
31·573			0			,,	,,	76·8
				29·6	1	,,	,,	98·
28·975			0			,,	9·5	33005·1
				28·8″	2	,,	,,	07·
28·545		28·57	4			,,	,,	09·5
27·817		27·82	1			,,	,,	17·6
				27·1	1n	,,	,,	25·
27·053		27·05	2			,,	,,	26·0
				26·0	1	,,	,,	37·
25·517		25·54	2			,,	,,	42·6
				25·3	2	,,	,,	45·
				24·6	1	,,	,,	53·
24·018	3024·019	24·06	3			,,	,,	58·9
23·164			0			,,	,,	68·4
22·673			0			0·85	,,	73·8
22·117			0			,,	,,	79·9
				21·2	1	,,	,,	90·
				20·8	1	,,	,,	94·
		20·60				,,	,,	96·5
19·928		19·95	0	20·0	6	,,	,,	33103·7
19·664		19·62″	2			,,	,,	07·1
19·569			2			,,	,,	07·8
18·194			0			,,	,,	22·9
17·225			1	17·2	2	,,	,,	33·5
16·930			1n			,,	,,	36·8
15·960			0			,,	,,	47·4
				15·0	1	,,	,,	58·
14·352		14·37	2			,,	,,	65·0
				11·8	1	,,	,,	93·
11·021			0			,,	,,	33201·8
				10·5	1n	,,	,,	08·
10·369			0			,,	,,	09·0
				09·7	4	,,	,,	16·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
3009·103		3009·10	1	3009·1c	6	0·85	9·5	33223·0
		07·38	1			,,	,,	42·0
				06·6	1	,,	,,	51·
05·929		05·91	2	06·0	1	,,	,,	58·2
04·565	3004·555	04·58	5	04·5	2	,,	,,	73·6
				02·4	1	,,	,,	97·
				02·2	1	,,	,,	99·
01·582			1			,,	,,	33306·3
				01·2	1	,,	,,	11·
				2998·0	1n	,,	,,	46·
		2997·45	1n	97·4	1	,,	9·6	52·1
				97·3	1	,,	,,	54·
				96·8	1	,,	,,	59·
				96·1	1	,,	,,	67·
2995·828			0			,,	,,	70·2
				95·7	2	,,	,,	72·
91·881		91·87	2			,,	,,	33414·2
				91·6″	1n	,,	,,	17·
				90·7	1	,,	,,	27·
90·158			0			,,	,,	33·4
90·048		90·07	0			,,	,,	34·5
			2	89·5	1n	,,	,,	41·
89·302			0			,,	,,	43·0
88·977		88·97	0	88·9b	6	,,	,,	46·7
88·487		88·47	0	88·4	4	,,	,,	52·2
87·568		87·56	3			,,	,,	62·5
				87·4	2	,,	,,	64·
87·117		87·11	5			,,	,,	67·5
				87·0	2	,,	,,	69·
				86·7	1	,,	,,	72·
86·330	2986·321	86·32	7			,,	,,	76·4
				86·2	4	,,	,,	78·
				85·2	1	,,	,,	89·
84·593			0			,,	,,	95·8
84·135			0			,,	,,	33500·9
				83·7	1	,,	,,	06·
83·194		83·20	4	83·2	1	,,	,,	11·5
82·514		82·51	3	82·5	1	0·84	,,	19·2
				81·9	1	,,	,,	26·
81·238		81·25	2	81·2	1	,,	,,	33·4
				79·6	1	,,	,,	52·
				79·5	1	,,	,,	53·
77·809		77·81	5			,,	,,	72·1
				77·7	2	,,	,,	73·
				76·5	1n	,,	,,	87
75·935		75·92	2			,,	,,	93·4
				75·7	1n	,,	,,	96·
				75·0	1	,,	,,	33604·
74·156		74·15	3	74·2	1	,,	,,	13·4
		73·28		73·2	1n	,,	,,	23·3
				72·6	1b	,,	,,	31·
71·741			0			,,	,,	40·7
				71·5	1	,,	,,	43·
70·807				70·8	1n	,,	9·7	51·2

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2968·790		2968·79	6	2968·7	4	0·84	9·7	33674·1
				68·2	1	,,	,,	81·
				67·1	1	,,	,,	93·
65·801			0			,,	,,	33708·0
		65·26	2	65·2	1	,,	,,	14·2
65·018			0			,,	,,	16·9
				64·8	1	,,	,,	19·
63·664		63·64	2	63·6b	10	,,	,,	32·5
				62·2	4	,,	,,	49·
61·805		61·78	2			,,	,,	53·7
60·773			0			,,	,,	65·3
60·686			0			,,	,,	66·3
				60·0	1	,,	,,	74·
59·769		59·76	4			,,	,,	76·8
59·478		59·48	1			,,	,,	80·0
58·899		58·89	4			,,	,,	86·7
				58·7	1	,,	,,	89·
58·504			0			,,	,,	91·2
				58·4	1	,,	,,	92·
				57·6	1	,,	,,	33801·
				57·5	1	,,	,,	03·
				57·0	1	,,	,,	08·
56·406			1			,,	,,	15·1
56·229			0			,,	,,	17·2
55·942			0			,,	,,	20·5
				55·7	1	,,	,,	23·
55·541		55·54	2	55·5	1	,,	,,	25·1
55·395		55·43	2			,,	,,	26·6
				53·9	1	,,	,,	44·
				53·5	1	,,	,,	48·
51·957			1			,,	,,	66·1
				50·6	1	,,	,,	82·
50·023		50·02	2n			,,	,,	88·4
				49·8	1	,,	,,	91·
49·475			1			,,	,,	94·6
				48·8	1	,,	,,	33902·
48·388			0			,,	,,	07·1
				48·1	4	,,	,,	10·
				47·6	4	,,	,,	16·
				46·7	4	,,	,,	27·
46·042		46·03	2	46·1	1	,,	,,	34·2
				44·9	4	,,	9·8	47·
42·116			0			0·83	,,	79·3
41·246		41·25	3	41·2	1	,,	,,	89·4
				40·6	1	,,	,,	97·
40·175			0			,,	,,	34001·8
				39·7	1	,,	,,	07·
39·588		39·58	2			,,	,,	08·6
38·403		38·39	2			,,	,,	22·4
				38·2	1b	,,	,,	25·
37·285			2			,,	,,	35·2
				36·0	1	,,	,,	50·
				35·2	1	,,	,,	59·
34·988			0			,,	,,	61·9

Rhodium—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2934·2	1	0·83	9·8	34071·
				33·3	1	,,	,,	81·
				32·6	1	,,	,,	90·
2932·065		2932·07	4	32·1	2	,,	,,	95·8
				31·6	1	,,	,,	34101·
29·256		29·25	4	29·2	2	,,	,,	28·6
28·559			0	28·6	2	,,	,,	36·4
27·062			0	27·0	6	,,	,,	54·5
26·953		26·94	0			,,	,,	55·5
				26·4b	1	,,	,,	62·
26·322			0			,,	,,	62·8
26·160			0			,,	,,	64·7
24·140		24·15	4	24·2b	8	,,	,,	88·2
23·239		23·23	4	23·2	1	,,	,,	98·9
21·229			0			,,	9·9	34222·3
				21·0	1	,,	,,	25·
20·296			1			,,	,,	33·2
				19·7	2	,,	,,	40·
17·028			0	17·0	1n	,,	,,	71·6
15·534		15·52	3	15·5	2	,,	,,	89·2
				15·0	2	,,	,,	95·
14·691			0			,,	,,	99·1
14·114		14·09	3			,,	,,	34306·0
13·715		13·70	2			,,	,,	10·7
				13·5	4	,,	,,	13·
13·474			0			,,	,,	13·4
13·185			0			,,	,,	16·8
12·746		12·74	3	12·7	1	,,	,,	22·0
10·281		10·30	4	10·3b	10	,,	,,	50·9
09·837			0			,,	,,	56·3
07·835			1			,,	,,	79·9
07·335		07·33	3	07·3	2	,,	,,	85·9
				07·1	2	,,	,,	89·
05·106		05·07	2			,,	,,	34412·4
				05·0	1	,,	,,	14·
				04·7	1	,,	,,	17·
04·440			0			,,	,,	20·1
				04·3	1	,,	,,	22·
				04·1	1	,,	,,	24·
03·960			0			0·82	,,	25·8
03·428			2			,,	,,	32·1
				03·0	1n	,,	,,	37·
02·975			0			,,	,,	37·5
00·080		00·07	4			,,	,,	71·9
				00·0	1	,,	,,	73·
2899·800		2899·79	2			,,	,,	75·3
				2899·0	1	,,	,,	85·
97·806			0			,,	,,	99·0
				97·7	4	,,	,,	34500·
97·171			0			,,	,,	06·5
				96·2	4	,,	10·0	18·
95·823			1			,,	,,	22·5
				95·7	2	,,	,,	24·
				93·3	1n	,,		53·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
2893·142			1			0·82	10·0	34554·5
92·817			4			,,	,,	58·4
92·320		2892·33	3			,,	,,	64·3
				2892·0	1n	,,	,,	68·
				91·0	1n	,,	,,	80·
				90·0	1	,,	,,	92·
89·962		89·96	3			,,	,,	92·5
89·623			1			,,	,,	96·6
				89·3	2n	,,	,,	34600·
89·222		89·21	3			,,	,,	01·5
88·986			0			,,	,,	04·2
				87·8	1	,,	,,	18·
87·082			0			,,	,,	27·0
86·112		86·10	3			,,	,,	38·8
				86·0″	1	,,	,,	40·
				85·4	1	,,	,,	47·
85·364			0			,,	,,	47·7
				85·0	1	,,	,,	52·
84·683		84·67	2			,,	,,	55·9
				84·3	2n	,,	,,	60·
				82·7	1	,,	,,	80·
82·497		82·50	4	82·5	1	,,	,,	82·1
				82·0	1	,,	,,	88·
81·400		81·39	2	81·4	1	,,	,,	95·4
80·912		80·91	2	81·0	4n	,,	,,	34701·2
80·775		80·80	1			,,	,,	02·8
79·628			0			,,	,,	16·7
				79·3	1	,,	,,	21·
78·770		78·76	4	78·7	1	,,	,,	27·1
				78·3	2n	,,	,,	33·
78·139			0			,,	,,	34·7
				78·0	1	,,	,,	36·
76·592			0			,,	,,	53·4
				76·2	1	,,	,,	58·
75·764			2			,,	,,	63·4
				75·5	1	,,	,,	67·
				74·6	4	,,	,,	77·
74·507			0			,,	,,	78·6
74·115		74·10	2			,,	,,	83·4
73·742		73·75	4	73·8	1	,,	,,	87·8
				73·2	2	,,	,,	94·
73·104			0			,,	,,	95·6
				72·0	1n	,,	10·1	34809·
71·489		71·49	5n			,,	,,	15·0
				70·8	1	,,	,,	23·
70·551		70·54	2	70·5	1	,,	,,	26·5
70·108		70·10	2			,,	,,	31·8
69·746			0			,,	,,	36·2
				69·0	1n	,,	,,	45·
68·400		68·37	2	68·4	1n	,,	,,	52·7
				68·3	2	,,	,,	54·
67·973			1			,,	,,	57·7
		67·55	1	67·5	2	,,	,,	62·9
65·755		65·75	2	65·8	2	,,	,,	84·7

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2864·7	1	0·81	10·1	34898·
2864·517		2864·51	3			,,	,,	99·8
				63·8	4	,,	,,	34909·
				63·2	4	,,	,,	16·
63·057		63·06	6			,,	,,	17·6
62·572			0			,,	,,	23·5
61·877			0			,,	,,	32·0
				61·7	1	,,	,,	34·
				61·0	1	,,	,,	43·
60·886		60·84	4			,,	,,	44·4
60·774			3			,,	,,	45·5
60·208			0			,,	,,	52·4
59·908		59·86	2			,,	,,	56·4
59·735		59·73	2	59·7	1	,,	,,	58·2
				58·2	1n	,,	,,	77·
				57·0	1	,,	,,	92·
		56·25	2	56·2	1	,,	,,	35000·8
55·273			4			,,	,,	12·8
54·848		54·84	2			,,	,,	18·1
				54·4	1	,,	,,	24·
54·237			0			,,	,,	25·5
				53·6	1	,,	,,	33·
				53·5	1	,,	,,	35·
				53·0	1	,,	,,	41·
52·809			0			,,	,,	43·1
52·459			1			,,	,,	47·4
				52·3	1n	,,	,,	49·
51·526			0	51·6	1	,,	,,	58·8
				51·2	1	,,	,,	63·
50·608			1			,,	,,	70·2
				50·5	2	,,	,,	71·
49·461		49·43	2			,,	,,	84·5
				48·9	1	,,	,,	91·
				48·5	1	,,	,,	96·
				47·7	1	,,	10·2	35106·
45·868		45·84	2	45·8b	8	,,	,,	28·6
44·917			0			,,	,,	40·2
				44·6	1b	,,	,,	44·
44·463		44·45	4n			,,	,,	45·9
				43·1	1n	,,	,,	63·
42·270		42·24	4n	42·3	1	,,	,,	73·2
41·909		41·90	4n			,,	,,	77·5
				41·0	2	,,	,,	89·
39·666			0			,,	,,	35205·2
38·425		38·40	2	38·4	1	,,	,,	20·8
				37·3	1n	,,	,,	35·
36·799		36·78	4	36·8	1	,,	,,	40·9
				36·5	1	,,	,,	45·
35·671		35·61	1	35·6	1	,,	,,	55·2
		35·52	1			,,	,,	56·7
34·990			1			,,	,,	63·3
				34·3	2	,,	,,	72·
34·233		34·22	3			,,	,,	72·8
33·981			1			,,	,,	75·9

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2833·4	2	0·82	10·2	35283·
2832·893		2832·87	2			"	"	89·6
				32·6	1	"	"	93·
31·398			0			"	"	35308·0
29·664		29·65	2			"	"	29·8
				29·5	1	"	"	32·
29·421		29·39	2			"	"	33·0
				28·5	1b	"	"	44·
28·259			0			"	"	47·2
				27·5	1	"	"	57·
27·433		27·41	4			"	"	57·7
				27·0	4	"	"	63·
26·798		26·78	4	26·8	2n	"	"	65·6
26·532		26·53	4			"	"	68·9
23·988			0			0·80	"	35400·7
23·756			0			"	10·3	03·5
23·504		23·47	2			"	"	06·9
22·979		22·97	2			"	"	13·3
22·850			0			"	"	14·9
				22·6	2	"	"	18·
				21·8	1	"	"	28·
21·620			1			"	"	30·3
				21·1	1	"	"	37·
20·946		20·95	3			"	"	38·8
				20·8	1	"	"	41·
19·742		19·72	3			"	"	54·1
				19·5c	8	"	"	57·
19·367		19·35	2			"	"	58·7
				18·7	1n	"	"	67·
16·979			1			"	"	88·7
				16·8	2	"	"	91·
14·817			0			"	"	35516·0
				13·9	2	"	"	28·
				13·4	2	"	"	34·
				12·9	2	"	"	40·
				12·3	1	"	"	48·
				11·6	1n	"	"	57·
10·999		11·00	3			"	"	64·2
				10·8	1	"	"	67·
09·853			0	09·8	1n	"	"	78·7
				07·6	1n	"	"	35607·
07·270		07·25	2			"	"	11·6
06·212			1			"	"	24·9
05·908		05·89	2			"	"	28·9
				05·7	2	"	"	31·
04·020		04·03	2	04·1	4	"	"	52·7
				02·4b	4	"	"	73·
02·113			0			"	"	77·1
				01·7	1	"	"	82·
01·674		01·68	3	01·6	1	"	"	82·6
				00·9	1n	"	"	93·
00·021			0			"	"	35703·7
2799·705			0			"	"	07·7
99·536			0			"	10·4	09·8

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2798·3	1	0·80	10·4	35726·
				97·9	1	,,	,,	31·
				97·1	1n	,,	,,	41·
2796·743		2796·75	3			,,	,,	45·4
				96·4	1	,,	,,	50·
95·824			2			,,	,,	57·2
				95·6	1n	,,	,,	60·
95·366		95·37	1			,,	,,	63·1
94·587			0			,,	,,	73·1
94·020			2	94·0	1	,,	,,	80·3
92·886		92·88	2	92·8	4	,,	,,	94·9
91·270		91·27	4	91·2	1n	,,	,,	35815·6
90·872		90·88	2	90·9	4	,,	,,	20·6
90·493		90·50	2			,,	,,	25·5
				89·1	1n	,,	,,	43·
86·934		86·93	2			,,	,,	70·6
85·920			0			,,	,,	84·4
				85·3	1	,,	,,	92·
				84·8	1	,,	,,	99·
				84·3″	1	,,	,,	35905·
				83·6	1	0·79	,,	14·
83·140		83·14	5	83·2	1	,,	,,	20·2
				82·8	1	,,	,,	25·
				82·0b	6	,,	,,	35·
81·184			1	81·2	1	,,	,,	45·5
				80·6	1n	,,	,,	53·
80·439		80·45	3			,,	,,	55·1
				79·8	1	,,	,,	63·
79·654		79·65	3			,,	,,	65·3
78·967		78·96	3			,,	,,	74·2
				78·8	1	,,	,,	76·
				78·4b	6	,,	,,	82·
78·162		78·16	4			,,	,,	84·6
				76·0	6	,,	,,	36013·
75·869		75·86	2			,,	,,	14·3
				75·2b	1	,,	10·5	23·
74·557		74·56	2			,,	,,	31·3
				74·4	4	,,	,,	33·
73·397			2			,,	,,	46·4
				73·2	4	,,	,,	49·
				72·5b	1	,,	,,	58·
71·615		71·63	4			,,	,,	69·4
				71·2	1	,,	,,	75·
70·277			1			,,	,,	87·0
68·336		68·33	4	68·3	1	,,	,,	36112·3
67·832		67·83	4	67·8	1	,,	,,	18·9
		66·64	1	66·6b	4	,,	,,	34·4
64·909		64·92	2	65·0	4	,,	,,	57·0
				64·2	1	,,	,,	66·
				64·0	1	,,	,,	69·
62·938		62·94	2			,,	,,	82·8
62·311			0	62·3	1	,,	,,	91·2
				61·3	2	,,	,,	36204·
60·541		60·55	2			,,	,,	14·2

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
				2759·7	1	0·79	10·5	36225·
				59·3	1n	,,	,,	31·
				57·6	1n	,,	,,	53·
2757·005			1			,,	,,	60·7
				56·9	2	,,	,,	62·
54·845			0			,,	,,	89·2
				54·3	4	,,	,,	96·
				53·3	1	,,	,,	36310·
				53·2	1	,,	,,	11·
				53·1	1	,,	,,	12·
52·941		2752·95	2			,,	,,	14·2
				52·3	2	,,	,,	23·
				51·6	1	,,	,,	32·
51·450		51·47	2			,,	,,	34·0
51·140			0			,,	10·6	38·0
		49·38	1			,,	,,	61·2
				48·4	1	,,	,,	74·
				47·7	4	,,	,,	83·
				45·8	1	,,	,,	36409·
				44·8	1b	,,	,,	22·
43·568		43·55	0			,,	,,	38·4
		41·85	2	41·8	1	0·78	,,	61·1
				41·7	1	,,	,,	63·
40·647		40·63	2			,,	,,	77·2
40·487			0			,,	,,	79·3
40·304		40·30	2			,,	,,	81·7
40·027		40·00	1	40·0b	S	,,	,,	85·6
39·845		39·80	1			,,	,,	88·1
38·359		38·34	2			,,	,,	36507·7
37·717		37·67	2			,,	,,	16·5
37·509		37·47	2	37·5b	S	,,	,,	19·2
36·860		36·84	3	36·8	1	,,	,,	27·9
				35·7	1	,,	,,	43·
				35·2	1	,,	,,	50·
34·906		34·89	2			,,	,,	53·8
				34·2	1	,,	,,	63·
32·261			0			,,	,,	89·1
31·874			0			,,	,,	94·3
				31·7	1	,,	,,	97·
				30·8	4	,,	,,	36609·
29·611			0	29·7	1	,,	,,	24·7
29·034		29·00	6	29·1b	6	,,	,,	32·6
				27·7	1	,,	,,	50·
26·934			0			,,	10·7	60·5
25·961			0			,,	,,	73·6
				25·8	1	,,	,,	76·
				25·1	1	,,	,,	85·
				24·1	1	,,	,,	99·
				23·1	1	,,	,,	36712·
				22·9	1	,,	,,	15·
22·389			0	22·3	1	,,	,,	21·7
22·243		22·23	2			,,	,,	23·8
		20·60	2	20·6	1	,,	,,	45·9
20·235		20·23	3			,,	,,	50·9

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
				2720·1	1	0·78	10·7	36753·
2718·640		2718·63	2			,,	,,	72·4
				18·5	1	,,	,,	74·
18·111			0	18·1	4	,,	,,	79·6
17·606		17·56	3			,,	,,	86·7
				17·4	1	,,	,,	89·
16·912		16·89	2			,,	,,	95·9
16·645			0	16·7	1	,,	,,	99·4
15·399		15·40	2	15·4b	8	,,	,,	36816·3
15·149		15·14	2			,,	,,	19·8
14·881			0			,,	,,	23·3
14·499		14·50	4			,,	,,	28·5
				14·3	1	,,	,,	31·
				13·3	2	,,	,,	45·
09·613		09·60	3			,,	,,	95·0
07·896			0n			,,	,,	36918·3
07·320		07·32	2	07·3	1	,,	,,	26·2
				06·7	2	,,	,,	35·
06·135			2			,,	,,	42·4
05·718		05·73	3	05·7b	10	,,	,,	48·0
05·059		05·05	0			,,	,,	57·1
				04·9	4	,,	,,	59·
03·820		03·84	6			,,	,,	73·9
				03·7	1	,,	,,	76·
				03·5	1	,,	,,	78·
				03·3	1	,,	,,	81·
02·621			0			,,	10·	90·3
02·337		02·33	2			,,	,,	94·3
02·158		02·17	2			,,	,,	96·6
				01·3	1	,,	,,	37008·
00·688		00·69	1	00·7	4	,,	,,	16·8
00·384		00·39	2			,,	,,	20·9
				2699·9	2	,,	,,	28·
				99·0	1n	,,	,,	40·
2697·955		2697·95	2			0·77	,,	54·3
				97·1	2	,,	,,	66·
				96·0	4	,,	,,	81·
94·405		94·40	4			,,	,,	37103·2
				94·3	2	,,	,,	05·
93·726		93·73	2n			,,	,,	12·5
				93·5	2	,,	,,	16·
				92·9	1	,,	,,	24·
92·390			2	92·4	1	,,	,,	30·9
				92·2	1	,,	,,	34·
				91·2	4	,,	,,	47·
				90·4	1	,,	,,	58·
89·716		89·71	0	89·7	4	,,	,,	67·9
89·022			0			,,	,,	77·4
				88·3	1	,,	,,	87·
88·173		88·18	2			,,	,,	89·1
87·411		87·40	2			,,	,,	99·8
87·015		87·01	3			,,	,,	37205·2
				86·7	1	,,	,,	10·
86·608		86·63	3			,,	,,	10·7

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2685·551			0			0·77	10·8	37225·5
				2684·4	8	,,	,,	41·
84·301		2684·30	2			,,	,,	42·9
83·660		83·66	0	83·7b	8	,,	,,	51·7
82·624		82·64	2			,,	,,	52·1
81·873		81·87	3			,,	,,	76·6
				81·7	4	,,	,,	79·
80·717		80·72	4			,,	,,	92·6
80·379		80·37	2			,,	,,	97·4
				78·8	1	,,	10·9	37319·
76·573		76·55	2			,,	,,	50·5
				76·4	4	,,	,,	53·
76·200		76·18	4			,,	,,	55·6
74·525		74·52	2	74·5c	8	,,	,,	79·0
74·287		74·29	2			,,	,,	82·1
74·059		74·05	2	74·0	2	,,	,,	85·5
				72·9	1	,,	,,	37402·
				72·2	1	,,	,,	11·
				72·0	1	,,	,,	14·
71·529			1			,,	,,	20·8
71·144		71·15	3	71·2	1	,,	,,	26·2
				70·1	1	,,	,,	41·
69·419			0			,,	,,	50·4
				69·3	4	,,	,,	52·
				68·5	2	,,	,,	63·
67·453			0			,,	,,	78·0
67·317			0			,,	,,	80·0
				67·2	2	,,	,,	82·
66·498		66·51	2			,,	,,	91·4
				65·3	1	,,	,,	37508·
				64·9	1	,,	,,	14·
				64·6	2	,,	,,	18·
63·764		63·77	2	63·7b	6	,,	,,	29·9
63·389			0			,,	,,	35·2
				62·1	1	,,	,,	53·
				61·7	1	,,	,,	59·
59·937			1			,,	,,	84·0
59·573			2			,,	,,	89·1
59·098		59·13	2	59·1b	8	,,	,,	95·7
58·515			0			,,	,,	37604·1
				58·4	2	,,	,,	06·
				57·3	4	,,	,,	21·
				56·4	1n	,,	,,	34·
56·000		56·00	2			,,	,,	39·7
52·750		52·76	5			0·76	11·0	85·7
				52·6	1	,,	,,	88·
51·973			0			,,	,,	96·8
				51·8b	10	,,	,,	99·
50·985			0			,,	,,	37710·8
49·686		49·69	1			,,	,,	29·3
				49·5	1	,,	,,	32·
				49·0	1	,,	,,	39·
48·681		48·67	2			,,	,,	43·7
47·375		47·38	3	47·3	1	,,	,,	62·2

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
		2647·07	1			0·76	11·0	37767·5
				2644·2	1	,,	,,	37808·
2643·691		43·68	2			,,	,,	15·0
43·077		43·10	3			,,	,,	23·5
42·857			0	42·8	4	,,	,,	26·8
				41·7	4	,,	,,	43·
				40·6	2n	,,	,,	59·
				39·8	1	,,	,,	71·
39·327			0			,,	,,	77·4
				39·2b	4	,,	,,	79·
39·097			0			,,	,,	80·7
38·839		38·84	2	38·8	4	,,	,,	84·4
38·388		38·39	0			,,	,,	90·9
37·484			0			,,	,,	37903·9
				37·0	1n	,,	,,	11·
36·744			1			,,	,,	14·6
				36·5	1	,,	,,	18·
		35·40	1			,,	,,	33·9
				35·3b	6	,,	,,	35·
35·082		35·07	3			,,	,,	38·6
34·605			0	34·6	4	,,	,,	45·4
33·523		33·50	2			,,	,,	61·1
33·373		33·40	2	33·4	1	,,	,,	62·9
				32·7	1	,,	,,	73·
				31·3	1	,,	,,	79·
30·509		30·49	2			,,	11·1	38004·4
				30·3b	4	,,	,,	07·
30·003		30·00	2			,,	,,	11·7
28·222		28·22	0	28·2b	8	,,	,,	37·4
				27·9	2	,,	,,	42·
27·042			0			,,	,,	54·5
26·776		26·77	2	26·7	4	,,	,,	58·4
25·973		26·00	3	26·0	1	,,	,,	69·9
25·496		25·51	1	25·5b	8	,,	,,	76·8
25·309		25·33	2			,,	,,	79·5
24·948		24·96	0			,,	,,	84·8
24·821			0	24·8	2	,,	,,	86·7
22·756		22·70	1			,,	,,	38117·1
22·661			4	22·6	2	,,	,,	18·1
				21·2	1	,,	,,	39·
21·099		21·12	2			,,	,,	40·7
				20·0	1	,,	,,	57·
				19·0	1	,,	,,	71·
18·596		18·61	3			,,	,,	77·2
				17·8	1n	,,	,,	89·
				17·1	1	,,	,,	99·
16·178		16·17	2			,,	,,	38212·7
				16·0	1	,,	,,	15·
15·735		15·74	2			,,	,,	19·0
				15·4"	1	,,	,,	24·
				14·7	1	,,	,,	34·
				13·8	1	,,	,,	47·
13·689		13·70	4n	13·6	1	,,	,,	48·9
13·145		13·19	0			,,	,,	56·6

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2612·315			0			0·76	11·1	38269·1
				2611·8	2	,,	,,	77·
				11·4	1	,,	,,	83·
				10·3	1	,,	,,	99·
10·156			0			,,	,,	38300·8
				09·7	1	0·75	,,	07·
09·266		2609·26	0			,,	11·2	13·8
				09·0b	8	,,	,,	18·
08·639		08·64	2			,,	,,	22·9
				08·3	1	,,	,,	28·
07·831		07·83	2			,,	,,	34·9
06·540		06·55	4	06·5	1	,,	,,	53·8
05·807		05·80	2			,,	,,	64·7
				04·3	2	,,	,,	87·
03·500		03·51	4			,,	,,	98·6
				03·3	2	,,	,,	38402·
01·926			0			,,	,,	21·9
				01·5	2	,,	,,	28·
				00·6	2	,,	,,	41·
				2599·7	1	,,	,,	55·
2599·352			0	99·4	1	,,	,,	59·9
				98·3	1	,,	,,	75·
98·166		2598·20	2			,,	,,	77·2
97·774		97·80	2	97·8	1	,,	,,	83·1
97·484						,,	,,	87·6
		97·16	0			,,	,,	92·4
97·014		97·06	3	97·0b	8	,,	,,	94·2
96·134			0			,,	,,	38507·6
				95·3	2	,,	,,	20·
				93·5	4	,,	,,	47·
92·247		92·26	0			,,	,,	65·3
				92·1b	6	,,	,,	68·
		90·91	1			,,	,,	85·3
				90·8	1	,,	,,	87·
89·892			1			,,	,,	38600·5
88·545		88·55	0n			,,	,,	20·5
87·353			0	87·3b	4	,,	11·3	38·2
87·245		87·25	2			,,	,,	39·8
86·897		86·90	2			,,	,,	45·0
				86·4	4	,,	,,	52·
84·016			1			,,	,,	88·1
				83·3	1	,,	,,	99·
				82·7	2	,,	,,	38708·
81·790		81·80	0			,,	,,	21·4
				81·6b	4	,,	,,	24·
81·100		81·14	2			,,	,,	31·6
				80·5	2	,,	,,	41·
80·043			0			,,	,,	47·7
				79·7	2	,,	,,	53·
79·650		79·64	0			,,	,,	53·7
79·487		79·49	2			,,	,,	56·1
				79·2	1	,,	,,	60·
				77·9	1	,,	,,	80·
				77·3	1n	,,	,,	89·

RHODIUM—*continued.*

Arc Spectrum: Wave-length: Kayser	Arc Spectrum: Wave-length: Rowland and Tatnall	Arc Spectrum: Wave-length: Exner and Haschek	Arc Spectrum: Intensity and Character	Spark Spectrum: Wave-length: Exner and Haschek	Spark Spectrum: Intensity and Character	Reduction to Vacuum: λ +	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
2576·330		2576·32	3			0·75	11·3	38803·7
		75·85	2			,,	,,	10·8
74·751		74·75	2	2574·7	1n	,,	,,	27·4
74·332		74·33	2n			,,	,,	33·8
73·577		73·60	2n			,,	,,	44·9
				71·6	1n	,,	,,	75·
				70·4	1	,,	,,	93·
70·206		70·20	2			,,	,,	96·1
69·171		69·16	0			,,	,,	38911·8
				69·0	4	,,	,,	14·
				68·8b	4	,,	,,	17·
67·374		67·37	4			,,	11·4	38·9
66·960		66·95	2	66·9	1	,,	,,	45·3
66·137		66·13	2			,,	,,	57·7
				66·0	1	,,	,,	60·
65·888		65·86	2			,,	,,	61·7
				65·1	2	,,	,,	73·
64·900			0			0·74	,,	76·5
				64·3	1	,,	,,	86·
				63·7	1	,,	,,	95·
62·741		62·75	0n			,,	,,	39009·2
				62·6	1	,,	,,	11·
				62·0	2	,,	,,	21·
60·322		60·33	2			,,	,,	46·1
		60·02	1			,,	,,	50·8
				59·8b	4	,,	,,	54·
58·714		58·76	4	58·7	1	,,	,,	70·4
				57·8	2	,,	,,	85·
				57·1b	6	,,	,,	95·
		56·98	1			,,	,,	97·2
56·172			1			,,	,,	39109·6
55·449		55·45	4			,,	,,	20·6
				55·3	2	,,	,,	23·
55·010		55·00	1			,,	,,	27·5
				54·7	1	,,	,,	32·
53·426		53·42	0n			,,	,,	51·7
				53·1	1	,,	,,	57·
				52·3	1	,,	,,	69·
51·289		51·30	2			,,	,,	84·4
				50·6	1	,,	,,	95·
				49·6	1	,,	,,	39210·
48·679		48·67	2			,,	11·5	24·6
		47·75	1			,,	,,	38·8
				47·6	1	,,	,,	41·
47·366			0			,,	,,	44·7
45·794		45·79	4			,,	,,	69·0
		45·44	1	45·4b	8	,,	,,	74·4
44·317		44·30	2			,,	,,	91·9
				44·0	4	,,	,,	97·
43·648		43·63	0			,,	,,	39302·3
				43·4	1	,,	,,	06·
41·096		41·11	2	41·1	2	,,	,,	41·5
39·860		39·88	4n			,,	,,	60·6
				39·7	1	,,	,,	63·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2539·2	1	0·74	11·5	39371·
				38·6″	1	,,	,,	80·
		2537·80	1			,,	,,	92·7
2537·721		37·72	2	37·7	4	,,	,,	93·9
37·155		37·16	3	37·1	1	,,	,,	39402·7
36·803		36·80	3	36·8	1	,,	,,	08·2
				36·2	1	,,	,,	18·
				35·7	1	,,	,,	25·
				35·3	2	,,	,,	32·
34·682			0	34·6	4	,,	,,	41·2
34·170		34·18	2			,,	,,	49·2
				34·0	1	,,	,,	52·
33·687		33·70	2			,,	,,	56·6
				33·5	2	,,	,,	60·
32·743		32·79	2			,,	,,	71·0
				32·3	2	,,	..	78·
31·920		31·85	2			,,	,,	84·8
31·369			0	31·3	4	,,	,,	92·8
31·053			0			,,	,,	97·7
30·284			0			,,	11·6	39509·7
				29·3	2	,,	,,	24·
				27·3	1	,,	,,	56·
		27·14	1			,,	,,	58·8
26·744			0	26·7	1	,,	,,	65·0
26·244		26·25	2			,,	,,	72·8
26·092		26·10	1			,,	,,	75·2
				26·0″	1	,,	,,	77·
25·221		25·21	0			,,	,,	89·0
		24·36	1			,,	,,	39602·4
				23·4	2	,,	,,	17·
22·988		22·98	2n			,,	,,	24·0
				22·7	1	,,	,,	28·
				21·4	1	,,	,,	49·
20·623		20·66	2			,,	,,	60·8
				20·5b	8	,,	,,	63·
				19·3	2	,,	,,	82·
18·561			0			,,	,,	93·6
				17·5b	4	0·73	,,	39710·
15·833		15·84	2			,,	,,	36·6
				15·7	1	,,	,,	39·
				15·3	2	,,	,,	45·
		14·82	1n			,,	,,	52·7
				14·7	1	,,	,,	55·
13·464		13·50	2			,,	,,	74·1
				13·3	1	,,	,,	77·
12·180		12·19	2′			,,	,,	94·4
11·133		11·15	2	11·2	2	,,	11·7	39810·8
		10·88	1			,,	,,	15·0
10·747		10·75	2			,,	,,	17·1
				10·6b	8	,,	,,	19·
09·788		09·81	2			,,	,,	32·1
				09·6	1	,,	,,	35·
08·743		08·73	0			,,	,,	49·0
				08·1	2	,,	,,	59·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	1/λ−	
2507·342		2507·35	0			0·73	11·7	39870·9
				2506·1	1	,,	,,	91·
05·758		05·76	2			,,	,,	96·4
05·189		05·20	2	05·1b	4	,,	,,	39905·4
04·384		04·39	4n			,,	,,	18·2
03·939			1			,,	,,	25·4
				03·8b	2	,,	,,	28·
03·458			0			,,	,,	33·0
02·843			1			,,	,,	42·9
02·546		02·55	2	02·6	1	,,	,,	47·5
				02·4	1	,,	,,	50·
				01·3	2	,,	,,	68·
01·115		01·10	1			,,	,,	70·6
00·740		00·74	0			,,	,,	76·5
00·668		00·67	2			,,	,,	77·6
		2499·81	1			,,	,,	91·3
				2499·2	2n	,,	,,	40001·
2499·095		99·10	2n			,,	,,	02·7
				98·1	2n	,,	,,	19·
				96·8	1n	,,	,,	40·
				96·0	1	,,	,,	52·
94·604		94·61	4n			,,	,,	74·8
				94·3	1	,,	,,	80·
93·733		93·73	1			,,	11·8	88·8
				93·4	1n	,,	,,	94·
92·395		92·39	2			,,	,,	40110·3
		91·93	1			,,	,,	17·8
				91·8b	4	,,	,,	18·
90·860		90·85	3			,,	,,	35·0
				90·7b	10	,,	,,	38·
89·986		89·98	0			,,	,,	49·1
				89·8	1	,,	,,	52·
				89·2	1	,,	,,	62·
88·547		88·54	1			,,	,,	72·3
				88·3	2	,,	,,	76·
		88·24	1			,,	,,	77·3
87·581		87·60	4			,,	,,	87·7
				86·7	1	,,	,,	40202·
85·688		85·67	2	85·7	4	,,	,,	18·6
				84·6	2n	,,	,,	36·
83·423		83·41	2n			,,	,,	55·3
				83·3	1	,,	,,	57·
				82·7	4	,,	,,	67·
		82·15	2			,,	,,	75·9
81·686			0			,,	,,	83·4
				81·2	2	,,	,,	91·
80·921		80·94	0			,,	,,	95·7
80·596		80·60	0			,,	,,	40301·1
				80·4	4	,,	,,	04·
		79·85	2			,,	,,	13·2
				79·1	1	,,	,,	25·
				78·6	1	,,	,,	34·
77·618		77·61	1	77·6	1	,,	,,	49·6
				77·2	2	,,	,,	56·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2475·978			0			0·73	11·9	40376·2
75·749		2475·72	0			,,	,,	80·1
				2475·6b	8	,,	,,	82·
75·097		75·11	4			,,	,,	90·5
74·677		74·67	1			,,	,,	97·5
74·116		74·12	0	74·1	1	,,	,,	40406·5
				73·4	1	,,	,,	18·
73·199		73·20	2			,,	,,	21·5
		73·00	1			,,	,,	24·8
72·571		72·56	2			,,	,,	31·9
				71·7	2	,,	,,	46·
71·561		71·56	2			,,	,,	48·4
70·860			0			,,	,,	59·8
				70·6	1	,,	,,	64·
70·486		70·50	2			,,	,,	65·9
				69·6	1	0·72	,,	80·
69·203		69·20	1			,,	,,	87·0
				68·8	1	,,	,,	94·
				68·2	1	,,	,,	40503·
				67·1	1	,,	,,	22·
				66·1	1	,,	,,	38·
				65·2	1n	,,	,,	53·
63·670		63·70	4n			,,	,,	77·7
				63·4	2	,,	,,	82·
		62·74	1			,,	,,	93·3
61·120		61·14	2			,,	,,	40619·8
				61·0b	8	,,	,,	22·
59·237			1			,,	12·0	51·0
59·004		59·00	2	59·0b	6	,,	,,	54·9
56·277		56·26	1	56·2b	4	,,	,,	40700·2
55·788		55·79	2	55·7	8	,,	,,	08·1
55·521			0			,,	,,	12·5
53·898			0			,,	,,	39·5
				52·1	1	,,	,,	69·
				51·0	1	,,	,,	88·
50·660		50·67	3			,,	,,	92·2
				50·5	1	,,	,,	96·
				49·5	1n	,,	,,	40813·
		49·15	2			,,	,,	18·5
48·923		48·92	2			,,	,,	22·3
				48·8	1n	,,	,,	24·
48·378		48·36	0			,,	,,	31·5
				47·8	4	,,	,,	41·
				47·4	1	,,	,,	48·
				46·8	1	,,	,,	58·
45·714		45·70	2			,,	,,	76·0
				45·2	2	,,	,,	84·
44·843			0	44·8	1	,,	,,	90·4
44·337		44·35	4n			,,	,,	98·8
				44·2	2	,,	,,	40901·
43·812			0			,,	12·1	07·6
43·221			0			,,	,,	17·5
42·830			0			,,	,,	24·0
				41·3	1	,,	,,	50·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
				2440·6	1	0·72	12·1	40961·
2440·427		2440·45	2			,,	,,	64·1
				39·8	1	,,	,,	75·
39·338			0			,,	,,	82·6
				38·7	4	,,	,,	93·
37·174		37·16	2			,,	,,	41019·1
36·974			0			,,	,,	22·4
				36·8	4	,,	,,	25·
				35·2	2	,,	,,	52·
				35·0	1	,,	,,	56·
				33·6	1n	,,	,,	79·
33·346			0	33·4	1n	,,	,,	82·7
32·755		32·75	1	32·7	1	,,	,,	93·6
		32·03	1			,,	,,	41105·8
31·936		31·94	2			,,	,,	07·4
				31·8	3	,,	,,	10·
				31·5	2	,,	,,	15·
				30·8	2	,,	,,	27·
				29·8b	2	,,	,,	44·
29·610		29·60	2			,,	,,	46·9
				29·5	2	,,	,,	49·
29·268			0			,,	,,	52·6
29 053			2	29·1	2	,,	,,	56·2
27·777		27·77	2			,,	12·2	77·8
27·193		27·20	3	27·2	2	,,	,,	87·5
				27·1b	4	,,	,,	89·
				26·5	2	,,	,,	99·
				25·4	1	,,	,,	41218·
24·521		24·51	0	24·5	2	,,	,,	33·2
				24·1	2	,,	,,	40·2
24·021		24·02	2			,,	,,	41·9
				23·8	1	,,	,,	45·
				23·5	2	,,	,,	50·
				23·2	2	,,	,,	56·
				22·6	1	,,	,,	66·
22·237			0	22·2	2	,,	,,	71·9
				21·9	1	0·71	,,	78·
21·060		21·05	2	21·0b	6	,,	,,	92·1
20·947			0	20·1	2	,,	,,	93·9
20·271		20·26	2			,,	,,	41305·6
		19·79	2			,,	,,	13·7
18·718		18·71	3			,,	,,	32·1
17·523			0	17·5	4	,,	,,	52·5
				16·8	2	,,	,,	65·
		15·93	2			,,	,,	79·7
				15·8b	6	,,	,,	82·
14·927			3			,,	,,	96·9
14·662			0	14·6	1	,,	,,	41401·5
14·433			0			,,	,,	05·4
				13·8	1	,,	,,	16·
12·613		12·61	1			,,	12·3	36·6
				11·9	1	,,	,,	49·
				10·6	4	,,	,,	71·
10·348		10·35	0			,,	,,	75·5

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2409·626		2409·62	0			0·71	12·3	41488·0
08·745			0			,,	,,	41503·1
				2408·6	2	,,	,,	06·
08·275		08·26	1			,,	,,	11·3
08·100		08·06	0			,,	,,	14·6
07·974		07·97	2			,,	,,	16·4
				07·8	1	,,	,,	19·
				06·9	1	,,	,,	35·
06·472			0			,,	,,	42·3
				05·3	4	,,	,,	63·
				04·0	1	,,	,,	85·
				03·3	2	,,	,,	97·
				00·6	2	,,	,,	41644·
				2399·3	1	,,	,,	67·
2399·044		2399·05	0			,,	,,	70·9
				98·9	1	,,	,,	73·
96·617		96·61	0	96·6b	8	,,	12·4	41713·1
				95·7	1	,,	,,	29·
				92·4b	8	,,	,,	87·
				90·7	4	,,	,,	41816·
				89·9	1	,,	,,	30·
				89·2	1	,,	,,	43·
				87·9	2	,,	,,	65·
86·489			0			,,	,,	90·1
86·222		86·23	4	86·2	2	,,	,,	94·8
				85·5	4	,,	,,	41908·
84·751		84·76	2			,,	,,	20·6
				83·6	4	,,	,,	41·
83·490		83·50	2			,,	,,	42·8
82·969		83·00	2	82·8	2	,,	12·5	51·7
				82·1	2	,,	,,	67·
				81·0	1	,,	,,	87·
				79·5	1n	,,	,,	42013·
		79·02	1			,,	,,	21·6
				78·0	4	,,	,,	40·
				76·8	1	,,	,,	61·
				76·4	1	,,	,,	68·
				75·0	2	,,	,,	93·
				73·7	1n	0·70	,,	42116·
				72·9	1	,,	,,	30·
				71·7	1	,,	,,	51·
				71·1	1n	,,	,,	62·
70·642		70·67	2			,,	,,	69·9
				70·3	1	,,	,,	76·
69·654		69·66	2	69·7	2n	,,	,,	87·7
		68·94	1n			,,	,,	42200·5
68·380		68·38	3			,,	12·6	10·4
		66·97	1	67·0″b	4	,,	,,	35·5
				66·4	1n	,,	,,	46·
				65·3	1n	,,	,,	65·
		64·74	1	64·8	2	,,	,,	75·3
				64·3	2	,,	,,	83·
				63·2	1	,,	,,	42303·
		62·01	1	62·2	1	,,	,,	24·2

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnal	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2361·6	1	0·70	12·6	42332·
		2361·25	1			,,	,,	37·8
				60·9	1	,,	,,	44·
				60·5	1	,,	,,	51·
				59·7	2	,,	,,	66·
		59·26	1	59·3	2	,,	,,	73·6
		58·55	1			,,	,,	86·3
				58·0	1	,,	,,	96·
				57·6	1	,,	,,	42403·
				56·3	1	,,	,,	27·
				55·8	1	,,	,,	36·
				55·2	1	,,	,,	47·
				54·2	1	,,	12·7	65·
				53·7	1	,,	,,	74·
				53·0	1n	,,	,,	86·
		52·55	1	52·5	1	,,	,,	94·4
				51·7	1	,,	,,	42510·
				51·3	1	,,	,,	17·
				50·4	1	,,	,,	33·
				49·7	1	,,	,,	46·
				48·0	2	,,	,,	77·
				47·2	1	,,	,,	91·
				46·8	2	,,	,,	99·
				46·5b	4	,,	,,	42604·
2345·597			1			,,	,,	20·4
				45·0	2	,,	,,	31·
				44·4	1n	,,	,,	42·
				43·6	1	,,	,,	57·
				43·3	1	,,	,,	62·
				42·5	2	,,	,,	77·
				41·8	1	,,	,,	89·
				40·1	1	,,	12·8	42720·
				38·6	1	,,	,,	48·
				36·9	2	,,	,,	79·
				35·9	1	,,	,,	97·
				35·2	2	,,	,,	42810·
		34·85	2	34·8b	6	,,	,,	16·5
34·762			1			,,	,,	18·1
		33·37	1	33·4	4	,,	,,	43·7
				29·5″	1n	,,	,,	42915·
28·737		28·74	2			,,	,,	28·9
				28·5	2	,,	,,	33·
				27·8b	4	,,	,,	46·
		26·56	1	26·5	1	,,	12·9	69·0
				25·5	1	0·69	,,	89·
				23·0	1	,,	,,	43035·
		22·68	1	22·6	1	,,	,,	40·8
		21·82	1	21·9	1	,,	,,	56·8
		19·95	1			,,	,,	91·5
19·173		19·18	2			,,	,,	43105·9
18·432		18·44	2			,,	,,	19·6
				17·4	1	,,	,,	39·
				16·6	1	,,	,,	54·
				14·2	1	,,	13·0	98·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
	Wave-length		Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
				2313·9	1	0·69	13·0	43204·
				13·5	1	,,	,,	12·
				12·6	2	,,	,,	28·
				11·6	1	,,	,,	47·
		2311·14	1			,,	,,	55·7
		09·89	1			,,	,,	79·1
				09·0	1	,,	,,	96·
2308·88			2			,,	,,	98·0
				08·2	1	,,	,,	43311·
				05·9	2	,,	,,	54·
				05·0	1	,,	,,	71·
				01·9	1	,,	,,	43429·
				00·5	1n	,,	13·1	56·
				2298·8	1	,,	,,	88·
				98·3	4	,,	,,	97·
		2294·54	1	94·6	2	,,	,,	43568·6
				94·2	4	,,	,,	75·
		93·35	1			,,	,,	91·2
				90·2	8	,,	,,	43651·
		90·10	1			,,	,,	53·1
				89·7	1	,,	,,	61·
		88·97	1			,,	,,	74·7
		88·61	1			,,	,,	81·5
				88·3	1	,,	13·2	87·
				86·2	1	,,	,,	43728·
				85·1	1	,,	,,	49·
				84·2	4	,,	,,	66·
				83·6	1	,,	,,	77·
				83·2	1	,,	,,	85·
				83·0	1	,,	,,	89·
				81·4	1	,,	,,	43820·
				81·2	1	,,	,,	23·
				80·9	1	,,	,,	29·
				80·1	1	,,	,,	45·
				78·1	1	,,	,,	83·
				78·0	1	,,	,,	85·
				77·3	1	0·68	,,	98·
		77·00	1	77·0	2	,,	,,	43904·2
				76·3	2	,,	,,	18·
				74·2	1	,,	13·3	58·
				73·7	1	,,	,,	68·
				71·5	1	,,	,,	44010·
				70·5	1	,,	,,	30·
				68·9	2	,,	,,	61·
				68·0	1	,,	,,	78·
				65·7	1n	,,	,,	44123·
				63·5	4	,,	,,	66·
				61·8	2	,,	13·4	99·
				58·6	1	,,	,,	44262·
				58·4	1	,,	,,	66·
				57·3	1	,,	,,	87·
				55·7	1	,,	,,	44319·
				55·5	2	,,	,,	23·
				50·9	2	,,	13·5	44413·

RHODIUM—*continued.*

Arc Spectrum				Spark Spectrum		Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length			Intensity and Character	Wave-length	Intensity and Character			
Kayser	Rowland and Tatnall	Exner and Haschek		Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
				2250·1	1	0·68	13·5	44429·
				49·7	1	,,	,,	37·
				48·7	1n	,,	,,	57·
				47·8	1n	,,	,,	74·
				47·0	1	,,	,,	90·
				41·0	1	,,	,,	44609·
				40·8	1	,,	,,	13·
				40·2	1	,,	,,	25·
				39·2	2	,,	,,	45·
				38·4	1	,,	13·6	61·
				37·7	2	,,	,,	75·
				37·2	1	,,	,,	85·
				36·7	1	,,	,,	95·
				36·5	1	,,	,,	99·
				36·0	1	,,	,,	44709·
				35·3	1	,,	,,	23·
				30·7	2	,,	,,	44815·
				29·2	1n	0·67	,,	46·
				28·3	1	,,	,,	64·
				26·7	2	,,	13·7	96·
				26·0	1	,,	,,	44910·
				25·1	2	,,	,,	28·
				22·0	1	,,	,,	91·
				20·9	1	,,	,,	45013·
				20·4	1	,,	,,	23·
				19·4	1	,,	,,	44·
				06·5	1	,,	13·8	45307·
				2199·0	1	,,	13·9	45461·
				96·2	1	,,	,,	45519·
				94·2	1	,,	,,	61·
				92·8	1	,,	,,	90·
				91·0	1	,,	14·0	45627·
				86·0	1	,,	,,	45732·
				82·0	1	,,	,,	45816.
				67·3	2	0·66	14·2	46126·

NOTE.—Lines marked *a* are resolved into *four* constituents in a very strong magnetic field, those marked *b* into triplets, those marked *c* into doublets (Purvis, *Proc. Cambridge Phil. Soc.*, xiii. p. 322).

Dynamic Isomerism.—Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Dr. T. M. LOWRY (*Secretary*), Professor SYDNEY YOUNG, Dr. J. J. DOBBIE, Dr. A. LAPWORTH, Dr. M. O. FORSTER, *and* Dr. C. H. DESCH. (*Drawn up by the Secretary.*)

ATTENTION has been directed during the past year mainly to a study of the influence of impurities on the velocity of mutarotation of nitrocamphor. In an earlier series of experiments on glucose[1] it was found that the mutarotation in aqueous solutions could not be retarded by the

[1] Lowry, *Trans. Chem. Soc.*, 1903, 83, 1314–1323.

addition of either acids or alkalis: the isomeric change thus appeared to be due to a direct interaction between the sugar and the water of low conductivity which formed the solvent. In the case of nitrocamphor dissolved in chloroform it has been found possible to check the mutarotation by the addition of N/100 acetic acid, and to stop it altogether during a period of three weeks by the addition of N/1,000 trichloracetic acid. The experiments therefore afford valuable confirmation of the view already arrived at[1] that the isomeric change which usually takes place when nitrocamphor is dissolved in chloroform or benzene does not occur spontaneously, but is conditioned by the presence of *minute traces of alkaline impurities.*

Experiments were made to determine quantitatively the effects produced by these impurities. Sodium ethoxide, added to an alcoholic solution of nitrocamphor, was found to produce an acceleration very similar to that which results from the addition of caustic potash to an aqueous solution of glucose; the mutarotation in presence of N/1,000 NaOEt was complete in about a quarter of an hour, with N/10,000 NaOEt in about three hours, and a slight acceleration could be detected in presence of N/100,000 NaOEt. The normal period of the isomeric change in absolute alcohol at 20° C. is about six hours, but the change is greatly accelerated by the addition of a little water. The velocity of change in alcohol containing 1 per cent. of water was exactly equal to that in a sample of 99·8 per cent. alcohol to which sodium ethoxide had been added in a concentration of N/10,000.

Extraordinary effects were produced by the addition of piperidine to solutions of nitrocamphor in benzene. In presence of N/1,000 piperidine the mutarotation was complete in two minutes, and even when working as rapidly as possible only two readings of the polarimeter could be obtained before the final value was reached. With N/10,000 piperidine the change was complete in about six minutes, with N/100,000 in an hour, and with N/1,000,000 in about ten hours. With N/10,000,000 piperidine the acceleration of the isomeric change was comparable with that due to the trace of impurity normally present in the purified materials, and no definite observations could be made.

In the case of the N/100,000 solution the molecules are present in the proportion—

piperidine : nitrocamphor : benzene = 1 : 25,000 : 1,000,000—

and about 2 per cent. of the nitrocamphor undergoes change in each minute. It therefore follows that if each molecule of piperidine is able to invert only one molecule of nitrocamphor at a time, it must accomplish 500 such inversions per minute, and unless selectively guided to the nitrocamphor must come in contact also with some 20,000 molecules of benzene.

In view of the remarkable effects produced by the addition of piperidine, it is noteworthy that the addition of aniline is almost without effect. In presence of N/1,000 aniline the velocity of isomeric change in a solution of nitrocamphor in benzene was slower than in presence of N/10,000,000 piperidine—a result that was confirmed by a second series of observations; the blank experiment, with benzene only, showed a still slower change, but this result was only achieved by very careful purification of the materials.

The experiments now described are of importance as indicating the conditions under which isomeric change may in general take place. It

[1] *Trans.*, 1899, 75, 221; *Report*, 1904, p. 196.

may be concluded that in neutral solvents, such as benzene and chloroform, no change can occur unless some third substance or impurity is present; the influence of the impurity may be greatly increased by raising the temperature or illuminating with ultra-violet light; but even under these conditions it is probable that isomeric change is not a spontaneous result of the interaction of solvent and solute.

The experimental evidence thus gives no support, but on the contrary is entirely opposed to the existence of the condition of intermolecular 'wobble' postulated by Laar[1] in his theory of 'tautomerism.' It is, moreover, very doubtful whether even the special case of the process of 'bond-shifting,' or 'desmotropy,'[2] which does not involve the transference of a mobile hydrogen atom, and which Baly[3] has described as 'isorropesis,' could occur in pure neutral solvents in the absence of a catalytic agent.

In addition to the investigation described above, considerable attention has been paid during the past year to the study of the optical properties of dynamic isomerides, and preparations have been made for a detailed examination of the relationship between the absorption spectra of isodynamic compounds and the velocity with which they undergo isomeric change.

The Study of Isomorphous Derivatives of Benzene-Sulphonic Acid.—Report of the Committee, consisting of Professors H. A. MIERS *(Chairman)*, H. E. ARMSTRONG *(Secretary)*, W. P. WYNNE, *and* W. J. POPE.

THE task undertaken is the preparation of all the possible isomeric sulphonic chlorides and sulphonic bromides of the isomeric dichloro-, the isomeric dibromo-, and of the isomeric chlorobromo-benzenes and to subject them to crystallographic study with the object of determining the extent of variation in the series of closely related compounds.

Apart from the labour entailed in measuring such a series, which is very great, much difficulty arises both in devising suitable methods of preparing the compounds and in obtaining properly developed crystals. It has not been found to be possible at present to prepare one of the three sets of 1 : 3 : 5 derivatives and one of the two sets of 1 : 2 : 3 derivatives. In the case of the 1 : 4 : 2 derivatives, whereas six of the eight compounds crystallise with the greatest readiness, the seventh is obtained only with difficulty in measurable forms; all attempts to grow measurable crystals of the eighth have been failures.

It is possible that the new conceptions introduced by Barlow and Pope may afford a clue to such peculiar differences. The investigation has certainly acquired increased importance in view of their conclusions, and will therefore be pushed forward during the coming year.

With the object of contrasting oxygen with sulphur, *p*-methoxy- and *p*-ethoxy-benzene-sulphonic chloride and bromide and the corresponding thio-compounds have been prepared and partially measured. The relationship between the corresponding oxygen compounds and between the corresponding thio-compounds appears to be of a simple character, only one axis being affected in the passage from the methyl to the ethyl compound; the effect of the displacement of oxygen by sulphur is less simple, however.

[1] *Ber.*, 1885, **18**, 648–657. [2] Jacobson, *Ber.*, 1888, **21**, 2628.
[3] Stewart and Baly, *Trans. Chem. Soc.*, 1906, **89**, 498.

The Applications of Grignard's Reaction.

By ALEX. MCKENZIE, *M.A., D.Sc., Ph.D.*

[Ordered by the General Committee to be printed *in extenso.*]

Introductory.

IN 1900 Victor Grignard[1] found that a vigorous action ensues when magnesium powder is added to a mixture of methyl iodide and anhydrous ether. The magnesium gradually dissolves with the formation of a clear solution from which, on evaporation of the ether, a crystalline grey hygroscopic solid is obtained. If an aldehyde (1 mol.) is added to the ethereal solution obtained from magnesium (1 mol.) and methyl iodide (1 mol.), a vigorous action again takes place with the formation of a magnesium organic compound, which, when decomposed by dilute acid, gives a good yield of the corresponding secondary alcohol.

Grignard found it possible by this method to obtain from benzaldehyde, for example, a satisfactory yield of phenylmethylcarbinol[2] and the action is represented in the following manner:—

$$CH_3I + Mg = CH_3MgI$$
$$CH_3MgI + C_6H_5 . CHO = C_6H_5 . CH(OMgI) . CH_3$$
$$C_6H_5 . CH(OMgI) . CH_3 + H_2O = C_6H_5 . CH(OH) . CH_3 + MgIOH$$

Ketones, in an analogous manner, are readily converted into tertiary alcohols; thus Grignard obtained phenyldimethylcarbinol from acetophenone:—

$$CH_3I + Mg = CH_3MgI$$
$$CH_3MgI + CH_3 . CO . C_6H_5 = (CH_3)_2C(OMgI) . C_6H_5$$
$$(CH_3)_2C(OMgI) . C_6H_5 + H_2O = (CH_3)_2C(OH) . C_6H_5 + MgIOH$$

In his first paper Grignard also points out that other alkyl halides may be substituted for methyl iodide with equally satisfactory results.

The successful application of the new reagent for the synthesis of alcohols from esters of aliphatic monobasic acids was described in the following year.[3] Formic esters are converted into secondary alcohols; for example, diethylcarbinol is obtained in a 73 per cent. yield from magnesium ethyl bromide and ethyl formate:—

$$C_2H_5Br + Mg = C_2H_5MgBr$$

$$C_2H_5MgBr + H . COOC_2H_5 = H . C\left\langle\begin{array}{l} OMgBr \\ C_2H_5 \\ OC_2H_5 \end{array}\right.$$

$$H . C\left\langle\begin{array}{l} OMgBr \\ C_2H_5 \\ OC_2H_5 \end{array}\right. + C_2H_5MgBr = H . C\left\langle\begin{array}{l} OMgBr \\ C_2H_5 \\ C_2H_5 \end{array}\right. + Mg\left\langle\begin{array}{l} OC_2H_5 \\ Br \end{array}\right.$$

$$H . C\left\langle\begin{array}{l} OMgBr \\ C_2H_5 \\ C_2H_5 \end{array}\right. + H_2O = H . C\left\langle\begin{array}{l} OH \\ C_2H_5 \\ C_2H_5 \end{array}\right. + MgBrOH$$

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[1] *Compt. rend.*, 1900, **130**, 1322.

[2] *Annales de l'Université de Lyon*, 1901, **6**, 1.

[3] *Compt. rend.*, 1901, **132**, 336.

Acetic esters, on the other hand, yield tertiary alcohols; for example, trimethylcarbinol is obtained in an 82 per cent. yield from methyl acetate:

$$\mathrm{CH_3MgI + CH_3 . COOCH_3 = CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{OCH_3}\end{matrix}\right.$$

$$\mathrm{CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{OCH_3}\end{matrix}\right. \mathrm{+ CH_3MgI = CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\right. \mathrm{+ Mg}\left\langle\begin{matrix}\mathrm{OCH_3}\\ \mathrm{I}\end{matrix}\right.$$

$$\mathrm{CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\right. \mathrm{+ H_2O = CH_3 . C}\left\langle\begin{matrix}\mathrm{OH}\\ \mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\right. \mathrm{+ MgIOH}$$

Tertiary alcohols may also be obtained from acid chlorides or acid anhydrides, the action of the magnesium alkyl halide again being assumed to take place in two phases.[1] Acetyl chloride, for instance, is readily converted into trimethylcarbinol:

$$\mathrm{CH_3MgI + CH_3 . COCl = CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{Cl}\end{matrix}\right.$$

$$\mathrm{CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{Cl}\end{matrix}\right. \mathrm{+ CH_3MgI = CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\right. \mathrm{+ MgICl}$$

$$\mathrm{CH_3 . C}\left\langle\begin{matrix}\mathrm{OMgI}\\ \mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\right. \mathrm{+ H_2O = CH_3 . C}\left\langle\begin{matrix}\mathrm{OH}\\ \mathrm{CH_3}\\ \mathrm{CH_3}\end{matrix}\right. \mathrm{+ MgIOH}$$

It was subsequently shown that aromatic halogen compounds behave like alkyl halides in forming magnesium organic compounds.[2] Thus phenyl bromide forms the compound C_6H_5MgBr, which, by its interaction with methyl benzoate, gives a theoretical yield of triphenylcarbinol. When magnesium phenyl bromide, however, acts on acetyl chloride, diphenylethylene, $(C_6H_5)_2C:CH_2$, is obtained in place of the alcohol $(C_6H_5)_2C(OH).CH_3$.

It was at once appreciated by students of organic chemistry that science was indebted to the French investigator for the discovery of a reagent of more than ordinary importance for synthetic purposes. As is well known, the classical work of E. Frankland and Duppa on zinc alkyl compounds opened up a highly fruitful field of research, to which important contributions were made by Wagner, Butlerow, and Saytzew. Zinc alkyl compounds are, however, difficult to manipulate on account of their spontaneous inflammability, and to this factor the comparatively limited

[1] Tissier and Grignard, *Compt. rend.*, 1901, **132**, 683.
[2] *Ibid.*, 1901, **132**, 1182.

extent of their application may be ascribed. Many of the reactions in which they play a part require weeks, or even months, for their completion, and the yields of the resulting compounds are often far from satisfactory. Magnesium organic compounds, on the other hand, are so much more easily prepared than zinc alkyl compounds; they are not inflammable on exposure to the atmosphere, and they can be manipulated with such facility that the older methods, depending on the use of zinc compounds, have been superseded. Not only is this the case, but Grignard's reagent has been applied for the preparation of carbon compounds by methods which earlier investigators did not have at their disposal.

Grignard was not the first to attempt the substitution of magnesium alkyl for zinc alkyl compounds for synthetic purposes. Fleck,[1] working in Lothar Meyer's laboratory, showed in 1893 that magnesium methyl interacts with acetyl chloride to form trimethylcarbinol; but, in spite of the reactivity of magnesium methyl, the method presented no advantages over the use of zinc alkyls; in fact it was less convenient, since magnesium alkyls are neither volatile nor soluble in the ordinary organic solvents.

In a paper which paved the way for the Grignard reaction, Barbier[2] showed that the zinc in Saytzew's reaction may be replaced by magnesium, and that it is not necessary actually to isolate magnesium methyl in order to use it subsequently for synthetic purposes. It was possible to obtain dimethylheptenol, $(CH_3)_2C : CH . CH_2 . CH_2 . C(OH)(CH_3)_2$, from methylheptenone, $(CH_3)_2C : CH . CH_2 . CH_2 . CO . CH_3$, by adding methyl iodide to an ethereal solution of the ketone in the presence of magnesium.

Grignard[3] was led to study magnesium organic compounds in consequence of this work of Barbier, and of an observation of E. Frankland and Wanklyn that the zinc compound $Zn(CH_3)_2,(C_2H_5)_2O$ is formed when methyl iodide is heated with zinc and anhydrous ether in a sealed tube.

In the present account of Grignard's action the more important applications will be indicated, but no attempt will be made to give a complete *résumé* of all the work carried out in this field. Section I. deals with the various types of synthesis accomplished by aid of Grignard's reagent, Section II. with some practical details, and Section III. with the theoretical aspect of the subject.

Section I.

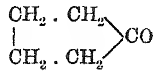
Alcohols and Phenols.

(a) *Secondary alcohols.*—A large number of secondary alcohols have been obtained from aldehydes or from formic esters by the method already indicated in the Introductory Section.

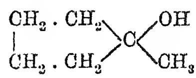
(b) *Tertiary alcohols.*—The mode of formation of tertiary alcohols from ketones, acid chlorides, acid anhydrides, and esters respectively has also been referred to. A large amount of work has been done in this particular branch, not only by Grignard himself, but, amongst others, by Acree, Béhal, Klages, W. H. Perkin, jun., Sachs, and Zelinsky.

[1] *Annalen*, 1893, **276**, 134. Compare Löhr, *ibid.*, 1890, **261**, 72.
[2] *Compt. rend.*, 1899, **128**, 110.
[3] *Revue générale des Sciences pures et appliquées*, 1903, **14**, 1041.

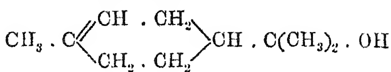
Cyclic ketones behave normally towards Grignard's reagent; thus Zelinsky [1] converted *cyclo*pentanone



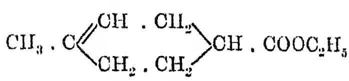
into methyl (1)-*cyclo*pentanol (1)



by means of magnesium methyl iodide. As an example of the application to a cyclic ester, Perkin's synthesis of terpineol,[2]



from ethyl Δ^3-tetrahydro-*p*-toluate



may be quoted.

Tertiary alcohols are also obtained by other methods of less importance for preparative purposes. Grignard [3] showed that when an ethereal solution of a magnesium alkyl halide is saturated with carbon dioxide, and the product then boiled with an excess of the reagent, trialkylcarbinols are obtained :—

$$RMgX + CO_2 = R . COOMgX$$

$$R . COOMgX + 2R'MgX = \left.\begin{matrix}R\\R'\\R'\end{matrix}\right\rangle C . OMgX + MgO + MgX_2$$

$$\left.\begin{matrix}R\\R'\\R''\end{matrix}\right\rangle C . OMgX + H_2O = \left.\begin{matrix}R\\R'\\R'\end{matrix}\right\rangle C . OH + Mg\left\langle\begin{matrix}OH\\X\end{matrix}\right.$$

As will be pointed out later, a general method for making carboxylic acids is to pass carbon dioxide through the Grignard reagent and then decompose the product by water; thus Zelinsky [4] describes the elegant method of obtaining benzoic acid by the action of carbon dioxide on magnesium phenyl iodide :—

$$C_6H_5I + Mg = C_6H_5MgI$$
$$C_6H_5MgI + CO_2 = C_6H_5 . COOMgI$$
$$C_6H_5 . COOMgI + H_2O = C_6H_5 . COOH + MgIOH$$

But this type of action is not always so simple. Schroeter [5] substituted phenyl bromide for the iodide in the making of the Grignard reagent, which with carbon dioxide gave triphenylcarbinol as the main

[1] *Ber.*, 1902, **35**, 2683.
[2] *Trans. Chem. Soc.*, 1904, **85**, 654.
[3] *Compt. rend.*, 1904, **138**, 152; *Bull. Soc. Chim.*, 1904 [3], **31**, 751.
[4] *Ber.*, 1902, **35**, 2692.
[5] *Ibid.*, 1903, **36**, 3005. Compare Meyer and Tögel, *Annalen*, 1906, **347**, 55.

product, whilst benzoic acid and benzophenone were also obtained. In fact the experimental conditions may be so adjusted[1] that no benzoic acid is obtained at all. The formation of triphenylcarbinol is represented as follows :—

$$C_6H_5MgBr + CO_2 = C_6H_5 . COOMgBr$$

$$C_6H_5 . COOMgBr + C_6H_5MgBr = \left.\begin{matrix} C_6H_5 \\ C_6H_5 \end{matrix}\right\rangle C \left\langle\begin{matrix} OMgBr \\ OMgBr \end{matrix}\right.$$

$$\left.\begin{matrix} C_6H_5 \\ C_6H_5 \end{matrix}\right\rangle C \left\langle\begin{matrix} OMgBr \\ OMgBr \end{matrix}\right. + C_6H_5MgBr = \left.\begin{matrix} C_6H_5 \\ C_6H_5 \\ C_6H_5 \end{matrix}\right\rangle C . OMgBr + MgO + MgBr_2$$

$$\left.\begin{matrix} C_6H_5 \\ C_6H_5 \\ C_6H_5 \end{matrix}\right\rangle C . OMgBr + H_2O = \left.\begin{matrix} C_6H_5 \\ C_6H_5 \\ C_6H_5 \end{matrix}\right\rangle C . OH + MgBrOH$$

Tertiary alcohols may also be obtained directly from carboxylic acids[2] by the action of an excess of the Grignard reagent ; thus phenyldiethylcarbinol, $C_6H_5(C_2H_5)_2C . OH$, is formed from benzoic acid and magnesium ethyl bromide. Metallic salts of carboxylic acids may be applied in a similar manner,[3] thus trimethylcarbinol is formed from potassium acetate and magnesium methyl iodide.

The synthesis of tertiary amino-alcohols from esters of amino-acids has been studied more particularly by Paal.[4] For example, magnesium phenyl bromide and ethyl glycollate, $NH_2 . CH_2 . COOC_2H_5$, form diphenylhydroxyethylamine, $NH_2 . CH_2 . C(OH)(C_6H_5)_2$.

After Houben[5] had shown that lactones when acted on by the Grignard reagent give tertiary alcohols, Paal and Hörnstein[6] prepared 1 : 1-diphenyl-*d*-sorbitol, $CH_2OH . (CHOH)_4 . C(OH)(C_6H_5)_2$, by acting on the acetyl derivative of *d*-gluconic lactone with magnesium phenyl bromide.

A very convenient method for preparing ditertiary glycols was employed by Valeur,[7] who acted on esters of dicarboxylic acids with an excess of the Grignard reagent ; in this manner methyl oxalate and magnesium phenyl bromide yield benzpinacone, $(C_6H_5)_2C(OH) . C(OH)(C_6H_5)_2$. Ditertiary glycols may also be obtained either from esters of ketonic acids or from diketones ; thus Grignard[8] obtained the glycol

$$CH_3 . C(OH)(C_5H_{11}) . CH_2 . CH_2 . C(OH)(C_5H_{11})_2$$

from magnesium *iso*amylbromide and ethyl lævulate,

$$CH_3 . CO . CH_2 . CH_2 . COOC_2H_5 ;$$

whilst Zelinsky[9] obtained the pinacone, $(CH_3)_2 . C(OH) . C(OH)(CH_3)_2$, from diacetyl, $CH_3 . CO . CO . CH_3$, and magnesium methyl iodide.

[1] *Ber.*, 1907, **40**, 1584.
[2] *Farbenfabriken vorm. F. Bayer and Co., D.R.-P.*, 1906, 166898.
[3] *Ibid.*, 1906, 166899.
[4] *Ber.*, 1905, **38**, 1686. Compare *ibid.*, 1906, **39**, 810, 2062, 4344.
[5] *Ibid.*, 1904, **37**, 489.
[6] *Ibid*, 1906, **39**, 1361, 2823, 2827.
[7] *Compt. rend.*, 1903, **136**, 694; *Bull. Soc. Chim.*, 1903, **29**, 683. Compare Dilthey and Last, *Ber.*, 1904, **37**, 2639.
[8] *Compt. rend.*, 1902, **135**, 627.
[9] *Ber.*, 1902, **35**, 2138.

Acree[1] shows that the action with a diketone may be regulated so that either one or both of the carbonyl groups react. It is possible, for example, to obtain from benzil, $C_6H_5 . CO . CO . C_6H_5$, either the keto-alcohol, phenylbenzoin, $(C_6H_5)_2C(OH) . CO . C_6H_5$, or benzpinacone, $(C_6H_5)_2C(OH) . C(OH)(C_6H_5)_2$.

The optically active glycol, tetraphenylerythritol,

$$(C_6H_5)_2C(OH) . CH(OH) . CH(OH) . C(OH)(C_6H_5)_2$$

has been obtained by P. F. Frankland and Twiss[2] by the action of magnesium phenyl bromide on dimethyl *d*-tartrate.

(c) *Primary alcohols.*—The Grignard reagent is not so useful for the preparation of primary alcohols as for the classes to which reference has been made. When a current of dry oxygen is passed into an ethereal solution of the Grignard reagent, oxidation takes place and a primary alcohol is formed when water is added,[3] *e.g.*,

$$\begin{array}{l} C_6H_5 . CH_2MgCl + O = C_6H_5 . CH_2OMgCl \\ C_6H_5 . CH_2OMgCl + H_2O = C_6H_5 . CH_2OH + MgClOH \end{array}$$

the yield of benzyl alcohol being 80 per cent.

When the Grignard reagent is heated for several days with trioxymethylene the primary alcohols are obtained, sometimes in good yield; thus *n*-propyl alcohol is obtained from magnesium ethyl bromide.[4]

Ethylene oxide may also be converted into primary alcohols,[5] for example, *n*-butyl alcohol is obtained from magnesium ethyl bromide.[6]

$$\left.\begin{array}{l} CH_2 \\ | \\ CH_2 \end{array}\right> O + Mg \left< \begin{array}{l} C_2H_5 \\ Br \end{array}\right. = \left.\begin{array}{l} CH_2 \\ | \\ CH_2 \end{array}\right> O \left< \begin{array}{l} C_2H_5 \\ MgBr \end{array}\right.$$

$$\rightarrow C_2H_5 . CH_2 . CH_2 . OMgBr \rightarrow C_2H_5 . CH_2 . CH_2OH$$

The action of ethylene monochlorohydrin on a magnesium organic compound takes place in two phases. The hydroxy-group is first acted on in the cold :—

$$RMgX + CH_2Cl . CH_2OH = RH + CH_2Cl . CH_2OMgX$$

On the addition of a second molecular proportion, R′MgX, which may be different from the first, a vigorous reaction again takes place when the ether is distilled off from the mixture and the temperature gradually raised :—

$$R'MgX' + CH_2Cl . CH_2OMgX = MgX'Cl + R' . CH_2 . CH_2 . OMgX$$

Phenylethyl alcohol, $C_6H_5 . CH_2 . CH_2OH$, is readily obtained in this manner from magnesium phenyl bromide.[7]

(d) *Phenols.*—Bodroux[8] applied for the preparation of phenols the method which Bouveault used for primary alcohols (*loc. cit.*), but the yields obtained were very small. The method appears, however, to be a

[1] *Ber.*, 1904, **37**, 2753. [2] *Trans. Chem. Soc.*, 1904, **85**, 1666.
[3] Bouveault, *Bull. Soc. Chim.*, 1903 [3], **29**, 1051.
[4] Grignard and Tissier, *Compt. rend.*, 1902, **134**, 107.
[5] Blaise, *ibid.*, 1902, **134**, 551.
[6] Grignard, *ibid.*, 1903, **136**, 1260; *Bull. Soc. Chim.*, 1903 [3], **29**, 944.
[7] Grignard, *Compt. rend.*, 1905, **141**, 44; *Bull. Soc. Chim.*, 1907 [8], **10**, 23.
[8] *Compt. rend.*, 1903, **136**, 158; *Bull. Soc. Chim.*, 1904 [3], **31**, 33.

general one. Thiophenols and selenophenols are formed in an analogous manner.[1]

The action on *p*-quinones has been investigated by Bamberger and Blangey,[2] who obtain quinols, but in small yield. Werner and Grob[3] find that phenanthrene quinone and magnesium phenyl bromide give 9 : 10-dihydroxydiphenyldihydrophenanthrene :—

$$\begin{array}{ll} C_6H_4 & CO \\ | & | \\ C_6H_4\,. & CO \end{array} \rightarrow \begin{array}{l} C_6H_4\,.\,C\!<\!\begin{array}{l}OH\\C_6H_5\end{array} \\ |\qquad\quad | \\ C_6H_4\,.\,C\!<\!\begin{array}{l}OH\\C_6H_5\end{array}\end{array}$$

Hydrocarbons.

(a) *Unsaturated hydrocarbons.*—When the Grignard reaction is applied to aldehydes, ketones, &c., sometimes an unsaturated hydrocarbon is obtained instead of an alcohol. It is in fact often possible to select the experimental conditions so that either an alcohol or the unsaturated hydrocarbon, obtained from it by the elimination of water, is the product of the action ; for example, Grignard[4] obtains phenyldimethylcarbinol, $C_6H_5\,.\,C(OH)(CH_3)_2$, from magnesium methyl iodide (1 mol.) and acetophenone (1 mol.). If, however, magnesium methyl iodide (2 mol.) is added to acetophenone (1 mol.) the ether expelled and the residue heated for six hours at 100°, the unsaturated hydrocarbon, metho-(1′)-vinylbenzene,

$$\begin{array}{l}C_6H_5\\CH_3\end{array}\!\!>\!C : CH_2$$

results.[5] Similarly, it is possible to prepare from mesityl oxide

$$\begin{array}{l}CH_3\\CH_3\end{array}\!\!>\!C : CH\,.\,CO\,.\,CH_3$$

either the hydrocarbon

$$\begin{array}{l}CH_3\\CH_3\end{array}\!\!>\!C : CH\,.\,C\!<\!\begin{array}{l}CH_3\\CH_2\end{array}$$ [6]

or the alcohol

$$\begin{array}{l}CH_3\\CH_3\end{array}\!\!>\!C : CH\,.\,C(OH)(CH_3)_2.$$ [7]

To quote a third example, Kay and Perkin,[8] starting with optically active ethyl Δ'-tetrahydro-*p*-toluate

$$CH_3\,.\,CH\!<\!\begin{array}{l}CH_2\,.\,CH\\CH_2\,.\,CH_2\end{array}\!\!>\!C\,.\,COOC_2H_5$$

---

[1] Wuyts and Cosyns, *Bull. Soc. Chim.*, 1903 [3], **29**, 689 ; Taboury, *Bull. Soc. Chim.*, 1904 [3], **31**, 1183.

[2] *Ber.*, 1903, **36**, 1625.

[3] *Ibid.*, 1904, **37**, 2892.

[4] *Compt. rend.*, 1900, **130**, 1322. Compare W. H. Perkin, jun., and Pickles, *Trans. Chem. Soc.*, 1905, **87**, 671.

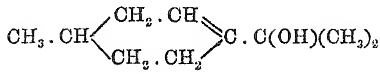
[5] Klages, *Ber.*, 1902, **35**, 2633.

[6] Grignard, *Compt. rend.*, 1900, **130**, 1324.

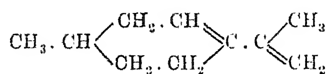
[7] Fellenberg, *Ber.*, 1904, **37**, 3578.

[8] *Trans. Chem. Soc.*, 1906, **89**, 839. Compare also *ibid.*, 1905, **87**, 1100.

obtain, by the action of magnesium methyl iodide, optically active Δ^3-*p*-menthenol (8)



When the latter compound, however, is simply left in contact with an ethereal solution of magnesium methyl iodide at the ordinary temperature, it is converted into the corresponding optically active unsaturated hydrocarbon, $\Delta^{3 \cdot 8(9)}$-*p*-menthadiene



In many cases only unsaturated hydrocarbons can be obtained and not the corresponding tertiary alcohols, if it so happens that the latter are very unstable. Klages, in particular, prepared a large number of unsaturated 1′-alkylated styrenes, of which an example has already been quoted, namely, metho-(1′)-vinylbenzene. When this hydrocarbon is reduced it is converted into *iso*propyl benzene, $C_6H_5 . CH(CH_3)_2$, with great ease. This method in the hands of Klages has proved highly useful for making a large number of saturated benzenoid hydrocarbons, which are difficult to prepare by other methods.

Various stilbene derivatives have been studied by F. and L. Sachs,[1] thus: *p*-dimethylaminobenzaldehyde, $(CH_3)_2N . C_6H_4 . CHO$, with magnesium benzyl chloride gives the alcohol

$$(CH_3)_2N . C_6H_4 . CH(OH) . CH_2C_6H_5$$

and this, on distillation under diminished pressure, forms 4-dimethylaminostilbene, $(CH_3)_2N . C_6H_4 . CH : CHC_6H_5$.

The same authors[2] acted on *p*-dimethylaminobenzaldehyde with magnesium methyl iodide and obtained methyl *p*-dimethylaminophenylcarbinol, $(CH_3)_2N . C_6H_4 . CH(OH) . CH_3$, from which, however, water was not eliminated in the manner expected. Klages' method of heating the reaction product with an excess of magnesium alkyl halide at 100° did not lead to the formation of dimethylaminostyrene, as was anticipated, but N-dimethylcumidine was formed thus:—

$$(CH_3)_2N . C_6H_4 . CH(OMgBr) . CH_3 + CH_3MgBr = (CH_3)_2N . C_6H_4 . CH(CH_3)_2 + MgO + MgBr_2$$

The formation of hydrocarbons of the acetylene series by aid of the Grignard action has been imperfectly studied. According to Oddo[3] magnesium bromoacetylene, $CH : CMgBr$, is produced when a current of dry acetylene is passed into magnesium phenyl bromide, and from this derivatives of the acetylene series are obtained.

(b) *Saturated hydrocarbons.*—Magnesium organic compounds are vigorously acted on by water with the production of hydrocarbons. This was one of the first observations which Grignard made with his reagents.[4]

[1] *Ber.*, 1905, **38**, 511.
[2] *Ibid.*, 1905, **38**, 517. Compare Sachs and Michaelis, *ibid.*, 1906, **39**, 2163.
[3] *Atti R. Accad. Lincei*, 1904 [5], **13**, 187.
[4] *Ann. Chim. Phys.*, 1901, **24**, 438; Tissier and Grignard, *Compt. rend.*, 1901, **132**, 835.

Methane, for example, is evolved by the addition of water to magnesium methyl iodide :

$$CH_3MgI + H_2O = CH_4 + MgIOH$$

An alcohol has the same effect as water; for example :—

$$CH_3MgI + C_2H_5OH = CH_4 + OC_2H_5 . MgI$$

Indeed, any compound containing a hydroxyl group behaves in this manner, this property of hydroxylic compounds having been recommended both as a means for their qualitative detection and for separating them from compounds which do not interact with the Grignard reagent.[1] A method for the estimation of hydroxyl groups in carbon compounds is based by Hibbert and Sudborough [2] on this reaction, where, however, amyl ether is substituted for ethyl ether in the preparation of the reagent. Zerewitinoff [3] claims the method to be suitable for estimating the number of hydroxyl groups in a carbon compound.

Allelotropic compounds generally act on the Grignard reagent in accordance with the hydroxylic structure, thus *l*-menthylacetoacetate reacts in accordance with the formula $CH_3 . C(OH) : CH . COOC_{10}H_{19}$ and not as $CH_3 . CO . CH_2 . COOC_{10}H_{19}$.[4]

A regular current of methane is evolved by the addition of dry powdered ammonium chloride to magnesium methyl iodide :—[5]

$$2CH_3MgI + NH_4Cl = 2CH_4 + NH_2 . MgI + MgICl$$

When a current of dry ammonia is passed into an ethereal solution of magnesium ethyl iodide, ethane is evolved :—

$$C_2H_5MgI + NH_3 = C_2H_6 + NH_2 . MgI$$

Primary or secondary amines exhibit a similar behaviour; thus with aniline and methyl aniline :—

$$C_2H_5MgI + C_6H_5 . NH_2 = C_2H_6 + C_6H_5 . NH . MgI$$
$$C_2H_5MgI + C_6H_5 . NHCH_3 = C_2H_6 + C_6H_5N(CH_3) . MgI$$ [6]

The action of a primary amine is possibly, however, more complex than this representation of Meunier, since Houben [7] concludes that the action

$$2CH_3MgI + C_6H_5NH_2 = C_6H_5NH . MgI, CH_3MgI + CH_4$$

takes place in the cold if the proportions of magnesium methyl iodide and aniline, indicated by the equation given, are used. If, however, a second molecular proportion of aniline is added to the hot solution, methane is again evolved, thus :—

$$C_6H_5 . NH . MgI, CH_3MgI + C_6H_5NH_2 = 2C_6H_5 . NHMgI + CH_4$$

A method for making aromatic hydrocarbons has been devised by Werner and Zilkens,[8] who use methyl sulphate ; thus *p*-xylene in a 75 per cent. yield is obtained from magnesium *p*-tolyl bromide :—

$$CH_3 . C_6H_4 . MgBr + (CH_3)_2SO_4 = C_6H_4(CH_3)_2 + CH_3 . SO_4 . MgBr$$

---

[1] Tschugaeff, *Ber.*, 1902, **35**, 3912.
[2] *Trans. Chem. Soc.*, 1904, **85**, 933.
[3] *Ber.*, 1907, **40**, 2023.
[4] McKenzie, *Trans. Chem. Soc.*, 1906, **89**, 380.
[5] Houben, *Ber.*, 1905, **38**, 3017.
[6] Meunier, *Compt. rend.*, 1903, **136**, 758 ; *Bull. Soc. Chim.*, 1903, **29**, 314.
[7] Houben, *Ber.*, 1905, **38**, 3017. Compare Sudborough and Hibbert, *Proc. Chem. Soc.*, 1904, **20**, 165.
[8] *Ber.*, 1903, **36**, 2116, 3618. Compare Houben, *ibid.*, 3083.

Toluene is obtained from magnesium phenyl bromide in a similar manner.

In order to throw some light on the constitution of triphenylmethyl, Gomberg and Cone [1] prepared tetraphenylmethane by the interaction of magnesium phenyl bromide and triphenylchloromethane :—

$$C_6H_5MgBr + (C_6H_5)_3CCl = (C_6H_5)_4C + MgClBr$$

The method renders possible the introduction of various radicals in place of the methane hydrogen atom in triphenylmethane ; for example, the asymmetrical tetraphenylethane is readily formed by aid of magnesium benzyl chloride :—

$$C_6H_5 . CH_2 . MgCl + (C_6H_5)_3CCl = (C_6H_5)_3C . CH_2C_6H_5 + MgCl_2$$

Triphenylchloromethane forms two isomeric magnesium compounds ; the α-form possibly has the formula

and the β-form

$$(C_6H_5)_3C . MgCl$$

each one of which appears to interact with triphenylchloromethane to give triphenylmethyl. The bearing of these isomeric compounds on the constitution of triphenylmethyl is at present under discussion.[2]

Acids.

(a) *Carboxylic acids.*—Grignard [3] was the first to study the action of carbon dioxide on magnesium alkyl halides ; he found, for example, that when a current of carbon dioxide is passed through an ethereal solution of magnesium methyl iodide, and the product then decomposed by dilute acid, acetic acid is formed :—

$$CH_3MgI + CO_2 = CH_3 . COOMgI$$
$$CH_3 . COOMgI + H_2O = CH_3 . COOH + MgIOH$$

This action has been extensively applied amongst others by Zelinsky,[4] Bodroux,[5] and especially by Houben. It has already been pointed out, however, that, under certain conditions, a carboxylic acid may result from this action either in very small yield or not at all (see Section on tertiary alcohols). The method, however, in most cases is very successful. Houben gives it as a general one for making aromatic and hydroaromatic carboxylic acids ; terephthalic acid, for example, is readily obtained from *p*-dibromobenzene. The yields are often exceedingly good ; for example, Schmidlin[6] obtains an 83 per cent. yield of triphenylacetic acid from triphenylchloromethane.

The action of the Grignard reagent on ethyl chlorocarbonate proceeds in two phases,[7] *e.g.* :—

$$(1)\ C_6H_5MgBr + Cl . COOC_2H_5 = C_6H_5 . COOC_2H_5 + MgClBr$$
$$(2)\ C_6H_5 . COOC_2H_5 \rightarrow (C_6H_5)_3C . OH$$

[1] *Ber.*, 1906, **39**, 1461, 2957. [2] Schmidlin, *ibid.*, 1907, **40**, 2316.

[3] *Annales de l'Université de Lyon*, 1901, **6**, 1 ; *Ann. Chim. Phys.*, 1901 [vii], **24**, 435.

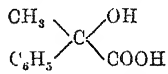
[4] *Ber.*, 1902, **35**, 2687, 2692, 4415 ; 1903, **36**, 208.

[5] *Bull. Soc. Chim.*, 1904 [3], **31**, 30. [6] *Ber.*, 1906, **39**, 628.

[7] Houben, *ibid.*, 1903, **36**, 3087.

Under suitable conditions, *i.e.*, by avoiding an excess of the Grignard reagent, ethyl benzoate is formed ; so that we have here another method of converting bromobenzene into benzoic acid, in addition to the one which involves the use of carbon dioxide.

The following method has been applied for obtaining hydroxy-acids. The action of the Grignard reagent on the ester of a ketonic acid may be so regulated that the carbonyl group is attacked, whereas the $-COOR$ group either survives the attack or is very slightly acted on ; thus menthyl benzoylformate, $C_6H_5 . CO . COOC_{10}H_{19}$, was converted by McKenzie [1] into benzilic acid, $(C_6H_5)_2C(OH) . CO_2H$, by means of magnesium phenyl bromide. The asymmetric synthesis of atrolactinic acid



may be accomplished either from benzoylformic acid, $C_6H_5 . CO . COOH$, or from pyruvic acid, $CH_3 . CO . COOH$, by aid of the same reaction. [2]

Another example of a compound presenting two points of attack is afforded by ethyl cyanoacetate. Here the $-COOR$ group may survive the attack of the Grignard reagent, and by taking advantage of this Blaise [3] was able to obtain esters of β-ketonic acids :—

$$COOC_2H_5 . CH_2CN + C_2H_5MgI \rightarrow COOC_2H_5 . CH_2 . C\begin{matrix} \nearrow N . MgI \\ \searrow C_2H_5 \end{matrix}$$

$$\rightarrow COOC_2H_5 . CH_2 . CO . C_2H_5 \text{ [4]}$$

(b) *Sulphur acids.*—Sulphinic acids are formed by the action of sulphur dioxide,[5] *e.g.*, benzenesulphinic acid is obtained from magnesium phenyl bromide :—

$$C_6H_5MgBr + SO_2 = C_6H_5 . SO_2MgBr$$
$$C_6H_5 . SO_2MgBr + H_2O = C_6H_5 . SO_2H + MgBrOH$$

Another method of obtaining sulphinic acids is described by Oddo,[6] who uses sulphuryl chloride. Benzenesulphinic acid is produced according to the scheme :—

$$(1)\ SO_2Cl_2 + C_6H_5MgBr = C_6H_5 . SO_2Cl + MgClBr$$
$$(2)\ C_6H_5 . SO_2Cl + C_6H_5MgBr = C_6H_5 . SO_2MgBr + C_6H_5Cl$$
$$(3)\ C_6H_5 . SO_2MgBr \rightarrow C_6H_5 . SO_2H$$

Weigert [7] shows that thiolic acids are obtained from carbonyl sulphide, which, *e.g.*, with magnesium ethyl bromide, gives thiolpropionic acid :

$$COS + C_2H_5MgBr = CS(C_2H_5) . OMgBr \rightarrow C_2H_5COSH$$

Carbithionic acids are described by Houben and his pupils,[8] who substitute carbon disulphide for carbon dioxide, thus :

$$CH_3MgI + CS_2 \rightarrow CH_3 . CSSMgI \rightarrow CH_3 . CSSH$$

---

[1] *Trans. Chem. Soc.*, 1904, **85**, 1261.

[2] McKenzie, *Trans. Chem. Soc.*, 1904, **85**, 1259 ; 1906, **89**, 365 ; McKenzie and Wren, *ibid.*, 1906, **89**, 688.

[3] *Compt. rend.*, 1901, **132**, 38, 478, 978.

[4] Compare Blaise's method for the preparation of ketones (see later).

[5] Rosenheim and Singer, *Ber.*, 1904, **37**, 2152.

[6] *Atti R. Accad. Lincei*, 1905 [v], **14**, I. 169.

[7] *Ber.*, 1903, **36**, 1007.

[8] *Ibid.*, 1902, **35**, 3696 ; 1906, **39**, 3219 ; 1907, **40**, 1303, 1725.

Those interesting acids are yellow, red, or violet oils, rather unstable, strong acids, which are readily oxidised to the disulphides, R . CS . S . S . CS . R.

Ketones.

Nitriles were converted into ketones by Blaise,[1] who obtains, *e.g.*, an 80 per cent. yield of phenylethyl ketone from magnesium ethyl iodide and benzonitrile :—

$$C_2H_5MgI + C_6H_5CN = C_6H_5 . C\begin{matrix}\diagup C_2H_5 \\ \diagdown\!\!\!\diagdown N . MgI\end{matrix}$$

$$C_6H_5 . C\begin{matrix}\diagup C_2H_5 \\ \diagdown\!\!\!\diagdown N . MgI\end{matrix} + H_2O = \begin{matrix}C_6H_5\diagdown \\ C_2H_5\diagup\end{matrix}C : NH + MgIOH$$

$$\begin{matrix}C_6H_5\diagdown \\ C_2H_5\diagup\end{matrix}C : NH + H_2O = NH_3 + C_6H_5 . CO . C_2H_5$$

The method, however, is not always so successful as in this particular case. Very varying yields were also obtained by Béis,[2] who investigated the action on acid amides, which were heated for several hours with an excess of the reagent. The action is represented as follows :—

$$R . CONH_2 + 2MgR'X = R . C(OMgX)(NHMgX)R' + R'H$$
$$R . C(OMgX)(NHMgX)R' + 2H_2O = R . C(OH)(NH_2)R' + MgX_2 + Mg(OH)_2$$
$$R . C(OH)(NH_2)R' = R . CO . R' + NH_3$$

I have been able to find in the literature very few cases where ketones have been obtained from acid chlorides ; the latter, of course, readily yield tertiary alcohols. It is difficult to arrest the action in the first phase, $R'COCl + RMgX = R' . CO . R + MgXCl$. Acree[3] obtains phenyl α-naphthyl ketone from benzoyl chloride and magnesium α-naphthyl bromide, but the yield is not stated. Gomberg and Cone[4] obtain benzophenone in small yield from benzoylchloride and magnesium phenyl bromide.

Benzophenone may be obtained together with benzoic and triphenylcarbinol by the action of carbon dioxide on magnesium phenyl bromide,[5] thus :—

$$C_6H_5MgBr \rightarrow C_6H_5 . COOMgBr \rightarrow (C_6H_5)_2C(OMgBr)_2 \rightarrow (C_6H_5)_2CO$$

But here, again, it has not been found possible to arrest the reaction so as to give a satisfactory yield of ketone. The method has also been applied by Bodroux[6] for obtaining dibromo- and dichloro-derivatives of benzophenone, but it cannot be quoted as a general method.

Kohler[7] finds on studying the action of unsaturated ketones that if a methyl group is attached to the carbonyl group of the ketone the reaction proceeds in the same manner as with a saturated ketone ; if,

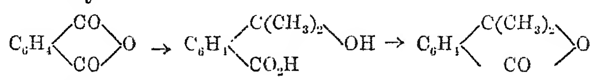
[1] *Compt. rend.*, 1901, **132**, 38; **133**, 299, &c. Compare also Béhal, *Bull. Soc. Chim.*, 1904 [3], **31**, 461.
[2] *Compt. rend.*, 1903, **137**, 575.
[3] *Ber.*, 1904, **37**, 625. [4] *Ibid.*, 1906, **39**, 2957.
[5] Schroeter, *ibid.*, 1903, **36**, 3005 ; 1907, **40**, 1584.
[6] *Compt. rend.*, 1903, **137**, 710.
[7] *Amer. Chem. Journ.*, 1904, **31**, 642 ; 1905, **33**, 21, 35, 153, &c. ; *Ber.*, 1905, **38**, 1203. Compare Bauer and Breit, *ibid.*, 1906, **39**, 1916.

however, a phenyl group is attached to the carbonyl group, a ketone is produced. Thus cinnamylidene acetophenone

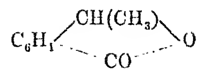
$$C_6H_5 \,.\, CH : CH \,.\, CH : CH \,.\, CO \,.\, C_6H_5$$

does not form, with magnesium phenyl bromide, the tertiary alcohol $C_6H_5 \,.\, CH : CH \,.\, CH : CH \,.\, C(OH)(C_6H_5)_2$, but gives β-phenyl β-styryl propiophenone, $C_6H_5 \,.\, CH : CH \,.\, CH(C_6H_5) \,.\, CH_2 \,.\, CO \,.\, C_6H_5$.

Bauer [1] obtains dialkylphthalides from phthalic anhydride; thus with magnesium methyl-iodide



α-Methyl phthalide



is obtained from phthaldehydic acid.[2]

Aldehydes.

Aldehydes are obtained, according to Bouveault,[3] from disubstituted formamides :—

$$H \,.\, CONRR' + R''MgX = HCR''(OMgX) \,.\, NRR'$$
$$HCR''(OMgX) \,.\, NRR' + H_2O = R'' \,.\, CHO + NHRR' + MgXOH$$

Benzaldehyde, for example, was formed from ethyl formanilide and magnesium phenyl bromide.

Bodroux [4] prepared a number of aldehydes in satisfactory yields from ethyl orthoformate; benzaldehyde, for example, was obtained in a 90 per cent. yield :—

$$CH(OC_2H_5)_3 + C_6H_5MgBr = MgBr(OC_2H_5) + C_6H_5 \,.\, CH(OC_2H_5)_2$$
$$C_6H_5 \,.\, CH(OC_2H_5)_2 + H_2O + HCl = 2C_2H_5OH + HCl + C_6H_5 \,.\, CHO$$

After Grignard had shown that secondary alcohols are formed from magnesium organic compounds (2 mols.) and formic esters (1 mol.), Gattermann and Maffezzoli [5] obtained aldehydes from magnesium organic compounds (1 mol.) and formic esters (3 mols.); secondary alcohols are formed at the same time, and the yields of aldehydes are not particularly good. The formation of *o*-toluyl aldehyde from *o*-bromotoluene is represented as follows :—

$$CH_3 \,.\, C_6H_4 \,.\, MgBr + H \,.\, COOC_2H_5 = BrMg \,.\, OC_2H_5 + CH_3 \,.\, C_6H_4 \,.\, CHO$$

Gattermann [6] shows that ethoxymethyleneaniline may be used in place of ethyl formate; anils are then formed from which aldehydes are obtained by the action of mineral acids, thus :—

$$C_6H_5 \,.\, N : CH \,.\, OC_2H_5 + RMgBr = C_6H_5 \,.\, N : CHR + C_2H_5OMgBr$$
$$C_6H_5 \,.\, N : CHR + H_2O = R \,.\, CHO + C_6H_5 \,.\, NH_2$$

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1 *Ber.*, 1904, **37**, 735; 1905, **38**, 240.
2 Simonis, Marben and Mermod, *ibid.*, 1905, **38**, 3981.
3 *Compt. rend.*, 1903, **137**, 987.
4 *Ibid.*, 1904, **138**, 92, 700. Compare Tschitschibabin, *Ber.*, 1904, **37**, 186, 850.
5 *Ber.*, 1903, **36**, 4152. Compare *Farbenfabriken vorm. F. Bayer and Co.*, *D.R.-P.*, 1904, 157573.
6 *Annalen*, 1906, **347**, 347. Compare Monier-Williams, *Trans.*, 1906, **89**, 273.

Sachs and Loevy[1] find that additive compounds are formed from *iso*nitriles, for which Nef's formulation, R . N : C, is taken. These additive compounds

$$R . N : C\begin{cases} \text{Aryl} \\ \text{Mg . Br} \end{cases}$$

when treated with mineral acids probably give first aldehydeimide derivatives R . N : CH . Aryl, and then aldehydes, O : CH . Aryl. The method, however, is not a very practical one.

Ethers.

Klages[2] has prepared a number of phenol ethers from aldehydes; for example, *o*-propenyl phenetole, $C_2H_5 . O . C_6H_4 . CH : CH . CH_3$, from ethyl salicylaldehyde and magnesium ethyl iodide.

According to Hamonet,[3] halogen-substituted methyl ethers interact with magnesium organic compounds, thus: $RMgX + XCH_2OR = MgX_2 + R . CH_2OR$.

Esters.

According to Grignard,[4] monoethyl ethylacetoacetate interacts with magnesium methyl iodide, partly in accordance with its ketonic structure, $CH_3 . CO . CH(C_2H_5) . COOC_2H_5$, to give the ester

$$(CH_3)_2C(OH) . CH(C_2H_5) . COOC_2H_5$$

Ethyl chlorocarbonate can be converted into ethyl benzoate by means of magnesium phenyl bromide when care is taken to avoid an excess of the latter by dropping it into an excess of the chlorocarbonate,[5] thus :—

$$C_6H_5MgBr + Cl . CO_2C_2H_5 = C_6H_5 . COOC_2H_5 + MgClBr$$

The reaction appears to be a general one.

Ethyl benzoate may also be prepared from magnesium phenyl bromide by a method described by Tschitschibabin,[6] who uses normal carbonic esters :—

$$RMgX + CO(OC_2H_5)_2 = RC(OMgX)(OC_2H_5)_2$$
$$RC(OMgX)(OC_2H_5)_2 + H_2O = R . COOC_2H_5 + C_2H_5OH + MgXOH$$

If the reaction between magnesium organic compounds and orthocarbonic esters is moderated and not too prolonged it proceeds thus :—

$$C(OC_2H_5)_4 + RMgX = R . C(OC_2H_5)_3 + MgX(OC_2H_5)$$

Houben[7] describes a method for the preparation of esters from alcohols or phenols. The alcohol or phenol is converted by means of magnesium alkyl chloride into its magnesium chloro-compound, which is then caused to interact with an acid chloride or anhydride, *e.g.*, with benzyl alcohol :—

$$C_6H_5 . CH_2OH + C_2H_5MgCl = C_6H_5CH_2OMgCl + C_2H_6$$
$$C_6H_5CH_2OMgCl + (CH_3CO)_2O = C_6H_5CH_2OCOCH_3 + CH_3 . COOMgCl$$

The preparation of the acetates of terpineol, linalool, thymol, and cis-terpin

[1] *Ber.*, 1904, **37**, 874.
[2] *Ibid.*, 1904, **37**, 3987.
[3] *Compt. rend.*, 1904, **138**, 813, 975; 1904, **139**, 59.
[4] *Ibid.*, 1902, **134**, 849.
[5] Houben, *Ber.*, 1903, **36**, 3087.
[6] *Ibid.*, 1905, **38**, 561.
[7] *D.R.-P.*, 1905, 162863; *Ber.*, 1906, **39**, 1736.

is described. The method gives excellent yields, and appears to be particularly suitable for the preparation of esters from unstable tertiary alcohols.

Nitrogen Compounds.

In continuation of his work on the formation of ketones from nitriles, Blaise[1] describes the preparation of anilides from phenyl *iso*cyanate, thus :—

$$C_6H_5 . N : C : O + RMgI = C_6H_5 . N : C\Big\langle{}^{OMgI}_{R}$$
$$\rightarrow C_6H_5 . N : C\Big\langle{}^{OH}_{R} \rightarrow C_6H_5NH . COR$$

Another method of obtaining anilides is given by Bodroux,[2] who uses the magnesium organic compounds of primary aromatic amines. This type, RNHMgI, is obtained either by adding the amine to a cold ethereal solution of magnesium methyl iodide, or by the action of equimolecular amounts of methyl iodide and amine on magnesium in the presence of ether. When an ester of a monobasic acid is then added, and the product decomposed as usual by dilute acid, an almost theoretical yield of anilide is obtained :—

$$2RNHMgI + R' . COOR'' = MgIOR'' + R' . C(NHR)_2 . OMgI$$
$$R' . C(NHR)_2 . OMgI + HCl = R . NH_2 + MgICl + R' . CO . NHR$$

The action of magnesium organic compounds on mustard oils is analogous to the action on *iso*cyanates. Sachs and Loevy[3] obtained a number of thioanilides according to the scheme

$$R . N : C : S + R'MgI = R . N : C(R') . S . MgI$$
$$R . N : C(R') . S . MgI + HCl = R . NH . CSR' + MgClI$$

Nitrosohydroxylamines are formed by the action of nitric oxide on the Grignard reagent, nitrosophenylhydroxylamine being formed, for example, in good yield from magnesium phenyl bromide :—[4]

$$NO \rightarrow O : N . N : O \rightarrow O : N . N\Big\langle{}^{OMgBr}_{C_6H_5} \rightarrow O : N . N\Big\langle{}^{OH}_{C_6H_5}$$

Since carbon dioxide and sulphur dioxide form carboxylic and sulphinic acids respectively with a Grignard reagent, Wieland[5] tried the action of nitrogen peroxide in the expectation of obtaining acids of the type R . NOOH. Instead of this type, however, he obtained, in the aliphatic series, $\beta\beta$-dialkylated hydroxylamines, R_2N . OH, the nitrogen peroxide undergoing reduction. The preparation of $\beta\beta$-diethylhydroxylamine is described. Negative results were obtained in the aromatic series.[6]

The action of magnesium phenyl bromide on β-phenylhydroxylamine has been investigated by Busch and Hobein,[7] who obtain a 20 per cent.

[1] *Compt. rend.*, 1901, **132**, 38, 478, 978.
[2] *Ibid.*, 1904, **138**, 1427.
[3] *Ber.*, 1903, **36**, 585 ; 1904, **37**, 874.
[4] Sand and Singer, *ibid.*, 1902, **35**, 3186 ; *Annalen*, 1903, **329**, 190.
[5] *Ber.*, 1903, **36**, 2315.
[6] Wieland and Gambarjan, *ibid.*, 1906, **39**, 1499.
[7] *Ibid.*, 1907, **40**, 2099.

yield of triphenylhydrazine. Possibly azobenzene is formed as an intermediate product, and then interacts thus :—

$$C_6H_5 . N : N . C_6H_5 + C_6H_5MgBr = \begin{matrix} C_6H_5 \\ C_6H_5 \end{matrix}\!\!>\!N-N\!<\!\!\begin{matrix} C_6H_5 \\ MgBr \end{matrix}$$

An alternative explanation is suggested as more probable. Phenylhydroxylamine is partially converted into diphenylamine, which then condenses with phenylhydroxylamine :

$$(C_6H_5)_2NH + OH . NHC_6H_5 = (C_6H_5)_2N . NHC_6H_5 + H_2O$$

It might be noted here that magnesium organic compounds sometimes exhibit a reducing action. Franzen and Deibel,[1] for example, show that hydrazobenzene may be obtained in good yield from azobenzene and magnesium ethyl bromide.

$$\begin{matrix} C_6H_5 . N \\ \| \\ C_6H_5 . N \end{matrix} + 2Mg\!<\!\!\begin{matrix} C_2H_5 \\ Br \end{matrix} = \begin{matrix} C_6H_5 . N . MgBr \\ | \\ C_6H_5 . N . MgBr \end{matrix} + C_4H_{10}$$

$$\begin{matrix} C_6H_5 . N . MgBr \\ | \\ C_6H_5 . N . MgBr \end{matrix} + 2H_2O = \begin{matrix} C_6H_5 . NH \\ | \\ C_6H_5 . NH \end{matrix} + 2MgBr(OH)$$

The action of the Grignard reagent on nitro-compounds has not been very thoroughly investigated. Moureu[2] obtained diethylhydroxylamine by the action of magnesium ethyl iodide on nitroethane and amylnitrite respectively. One of the products resulting from the action of magnesium ethyl iodide on nitrobenzene is ethyl aniline.[3]

A method of obtaining secondary amines from alkylidene bases is described by Busch ;[4] thus C-methyl benzylaniline is obtained from magnesium methyl iodide and benzylidene aniline :

$$C_6H_5 . N : CH . C_6H_5 + MgCH_3I = C_6H_5 . \underset{\displaystyle MgI}{\underset{|}{N}}—\underset{\displaystyle CH_3}{\underset{|}{CH}} . C_6H_5$$

$$C_6H_5 . \underset{\displaystyle MgI}{\underset{|}{N}}—\underset{\displaystyle CH_3}{\underset{|}{CH}} . C_6H_5 + H_2O = C_6H_5NH . CH(CH_3) . C_6H_5 + MgIOH$$

The action on oximes has been studied by Busch and Hobein,[5] and takes place in accordance with the scheme

$$R . CH : N . OH + 2R'MgX = \begin{matrix} R \\ R' \end{matrix}\!\!>\!CH . N\!<\!\!\begin{matrix} R' \\ MgX \end{matrix} + Mg\!<\!\!\begin{matrix} OH \\ X \end{matrix}$$

$$\begin{matrix} R \\ R' \end{matrix}\!\!>\!CH . N\!<\!\!\begin{matrix} R' \\ MgX \end{matrix} + H_2O = \begin{matrix} R \\ R' \end{matrix}\!\!>\!CH . NHR' + Mg\!<\!\!\begin{matrix} OH \\ X \end{matrix}$$

According to F. and L. Sachs,[6] tertiary amines combine with magnesium organic compounds to form compounds which are insoluble in

[1] *Ber.*, 1905, **38**, 2716. [2] *Compt. rend.*, 1901, **132**, 837.
[3] Oddo, *Atti R. Accad. Lincei*, 1904 [v], **13**, II. 220.
[4] *Ber.*, 1904, **37**, 2691. Compare Busch and Rinck, *ibid.*, 1905, **38**, 1761.
[5] *Ibid.*, 1907, **40**, 2096.
[6] *Ibid.*, 1904, **37**, 3088. Compare Oddo, *Atti R. Accad. Lincei*, 1904 [v], **13**, I. 100.

ether; the compound of quinoline and magnesium phenyl bromide is represented as $C_9H_7N \cdot (MgBr)C_6H_5$.

Forster and Judd,[1] in studying the action of magnesium methyl iodide on α-cyanocamphor, found that about 80 per cent. of the latter compound escaped attack by the reagent, whilst the remainder was converted into the imine

$$C_8H_{14}\left\langle\begin{array}{l} CH \cdot C(CH_3):NH \\ | \\ CO \end{array}\right.$$

which on hydrolysis gave acetylcamphor.

When normal ethyl carbonate is added to the magnesium compound of a primary aromatic amine, one obtains a monosubstituted urethane,[2] thus:—

$$2C_6H_5NHMgI + CO(OC_2H_5)_2 = (C_6H_5 \cdot NH)_2C(OC_2H_5) \cdot OMgI + MgI(OC_2H_5)$$
$$(C_6H_5 \cdot NH)_2C(OC_2H_5) \cdot OMgI + H_2O = C_6H_5NH_2 + C_6H_5NH \cdot COOC_2H_5$$

The application of the Grignard reagent for the preparation of diazoamino-compounds has been the subject of a series of papers by Dimroth.[3] These compounds are obtained from diazobenzeneimide according to the scheme

$$C_6H_5 \cdot N\left\langle\begin{array}{l} N \\ \| \\ N \end{array}\right. + RMgX = C_6H_5 \cdot N(MgX) \cdot N:NR$$

$$C_6H_5 \cdot N(MgX) \cdot N:NR + H_2O = C_6H_5 \cdot NH \cdot N:NR + MgXOH$$

The method is particularly useful for the preparation of aliphatic or mixed aliphatic-aromatic diazoamino-compounds, for the preparation of which the older method of Griess is not available. Thus phenylmethyltriazene, $CH_3 \cdot N_3H \cdot C_6H_5$, benzylmethyltriazene, $CH_3 \cdot N_3H \cdot CH_2\,C_6H_5$, &c., have been prepared. Diazoaminomethane, $CH_3 \cdot N:N \cdot NH \cdot CH_3$, was prepared from methylazide, $CH_3 \cdot N\left\langle\begin{array}{l} N \\ \| \\ N \end{array}\right.$, and magnesium methyl iodide, according to the scheme given above. The isolation of this interesting compound was accompanied with great difficulties, due, on the one hand, to its instability, and, on the other, to the ease with which it dissolves in all solvents tried.

Alkyl and Aryl Metallic Compounds.

Pfeiffer and Schnurmann[4] describe a method of preparing alkyl and aryl metallic compounds by interaction of metallic halides and the Grignard reagent either at the ordinary temperature or at 100°. Tin tetraethyl, for example, is prepared from tin tetrabromide and magnesium ethyl bromide:—

$$SnBr_4 + 4C_2H_5MgBr = Sn(C_2H_5)_4 + 4MgBr_2$$

Other tin compounds, such as tin tetraphenyl, tin tribenzyl chloride, tin trimethyl iodide, &c., are also obtained by this method, which has also

[1] *Trans. Chem. Soc.*, 1905, **87**, 368.
[2] Bodroux, *Compt. rend.*, 1905, **140**, 1108.
[3] *Ber.*, 1903, **36**, 909; 1905, **38**, 670; 1906, **39**, 3905.
[4] *Ibid.*, 1904, **37**, 319, 1125, 4617, 4618, &c.

been applied for making lead compounds; for example, lead tetraphenyl is obtained from lead chloride:

$$2PbCl_2 + 4C_6H_5MgBr = Pb + Pb(C_6H_5)_4 + 4MgClBr$$

The method has been very extensively applied, more particularly by Pfeiffer, for the preparation of derivatives of other elements such as mercury, thallium, phosphorus, arsenic, antimony, bismuth, and platinum.

Kipping[1] has made a special study of silicon compounds, and by aid of the Grignard reaction has prepared *dl*-sulphobenzylethylpropyl silicyl oxide

$$\begin{array}{c} \qquad\qquad\qquad\quad C_2H_5 \quad\;\; C_2H_5 \\ \qquad\qquad\qquad\quad | \qquad\quad | \\ SO_3H\,.\,C_6H_4\,.\,CH_2\,.\,Si{-}O{-}Si\,.\,CH_2\,.\,C_6H_4\,.\,SO_3H \\ \qquad\qquad\qquad\quad | \qquad\quad | \\ \qquad\qquad\qquad\quad C_3H_7 \quad\;\; C_3H_7 \end{array}$$

and obtained evidence of the resolution of this compound into optically active components. Incidental to this work a number of silicon compounds are described, such as phenylethylsilicon dichloride, $C_2H_5(C_6H_5)SiCl_2$, phenylethylpropylsilicyl chloride, $C_2H_5(C_3H_7)(C_6H_5)SiCl$, phenylbenzylethylpropylsilicane, $C_2H_5(C_3H_7)(C_6H_5)(C_7H_7)Si$, benzylethylsilicon di-chloride, $C_2H_5(C_7H_7)SiCl_2$, benzylethylpropylsilicyl chloride, $C_7H_7(C_2H_5)(C_3H_7)SiCl$, &c.

Section II.

Preparation of the Grignard Reagent.

It is of paramount importance that the materials used in the preparation of the Grignard reagent should be as dry as possible. The following description of the preparation of magnesium methyl iodide is given by Grignard.[2] The magnesium (24 grams, 1 atom) is placed in a round-bottomed flask to which are attached a dropping-funnel and a reflux condenser. Methyl iodide (1 mol.) is mixed with an equal volume of anhydrous ether and 25–30 c.c. of the mixture added to the magnesium. After a few minutes a vigorous action takes place, and at this stage 200–250 c.c. of anhydrous ether are added; the rest of the mixture of methyl iodide and ether is then gradually added by means of the dropping-funnel. Finally the mixture is warmed if necessary—that is, if the magnesium has not already been all dissolved. Under these conditions one obtains an almost colourless liquid, and there is practically no sediment.

In preparing magnesium methyl iodide in much smaller quantity than indicated by Grignard in the preceding description, the magnesium may be placed in a round-bottomed flask, connected with a condenser, which is provided with a tube, containing calcium chloride and soda lime. The mixture of methyl iodide and about four times its volume of ether is then added in one lot to the magnesium. The action is moderated, if necessary, by immersing the flask in ice-cold water.

The following points regarding the preparation of the reagent may be noted:—

(1) *Magnesium.*—Powder, ribbon, or filings are employed by various

[1] *Trans. Chem. Soc.*, 1907, **91**, 209, 717.

[2] *Revue générale des Sciences pures et appliquées*, 1903, **14**, 1041.

investigators. The filings provided by the Aluminium- and Magnesium-Fabrik, Hemelingen, bei Bremen, are very suitable; according to Klages they contain 99·7–99·8 per cent. of magnesium. Evidence is not wanting to show that impurities in the magnesium sometimes affect the reaction. Beckmann [1] shows that calcium may be substituted in certain cases for magnesium, but the method does not appear to present any advantages over the usual one.

(2) *Ether.*—The ether should be thoroughly dried by the following method, for example. Wash with water, dry with calcium chloride, filter, add sodium wire, distil over sodium wire and then over phosphorus pentoxide.[2] Ullmann and Münzhuber [3] prepare their anhydrous ether by shaking 300 c.c. of ordinary ether (sp. gr. 0·722) with a mixture of 25 c.c. of concentrated sulphuric acid and 25 c.c. of water and then allowing the product to remain for one to two hours over a little sodium wire.

The presence of the merest trace of water is shown up, in the carrying out of a Grignard action, by the slight turbidity which appears when the action starts, and which thereafter disappears.

That the method of drying the ether may have an important influence on the progress of the action is indicated by the experience of Ahrens and Stapler.[4] In their first communication on the use of dihalogenides those authors showed that ethylene dibromide readily interacts with magnesium and ether to form the compound $MgBr.CH_2.CH_2Br,(C_2H_5)_2O$. Since, however, on repetition of this experiment with the same samples of magnesium and ethylene dibromide the chief product was magnesium bromide, it was obvious that the action depended on the state of the ether. Experiments showed how varying the results were, according to the manner in which the ether was dried.

It should also be remembered that the ether may contain negative catalysers, which may either retard the action or prevent it. Bischoff [5] points out, for example, that magnesium is not dissolved by a mixture of ethylene dibromide and ether in the presence of a little acetone or acetophenone when the mixture is allowed to remain for a night at the ordinary temperature or when it is boiled. This action of a negative catalyser very likely accounts for the fact that occasionally one investigator finds the preparation of some particular Grignard reagent to proceed with ease, whilst another encounters difficulties.

(3) *Halogen compound.*—This ought also to be as free from moisture as possible. It does no harm to distil before use.

The ease with which the Grignard reagent is made depends on the particular halide used. Sometimes the action begins of its own accord with readiness, as in the case of magnesium methyl iodide. Sometimes the mixture requires to be heated, but when once started the action proceeds to a completion after the source of heat has been withdrawn. In other cases the mixture must be continuously heated. Occasionally a catalyser is necessary to start the action vigorously.

It frequently happens that, in addition to the formation of the Grignard reagent, a secondary reaction takes place,[6] namely, the formation of saturated hydrocarbons by the action of magnesium on the halide,

[1] *Ber.*, 1905, **38**, 904.
[2] Compare Perkin and Pickles, *Trans. Chem. Soc.*, 1905, **87**, 647.
[3] *Ber.*, 1903, **36**, 406. [4] *Ibid.*, 1905, **38**, 1296, 3259. [5] *Ibid.*, 1905, **38**, 2078.
[6] Tissier and Grignard, *Compt. rend.*, 1901, **132**, 835; Tschelinzeff, *J. Russ. Phys. Chem. Soc.*, 1904, **36**, 549; Tiffeneau, *Compt. rend.*, 1904, **139**, 481.

for instance, $2C_6H_5Br+Mg=MgBr_2+C_6H_5.C_6H_5$. Diphenyl is always formed in this manner in the preparation of magnesium phenyl bromide. With alkyl halides with low molecular weight this secondary reaction is not pronounced, but with halides of higher molecular weight it is difficult to work with calculated amounts owing to this reaction taking place to a marked extent. According to Grignard,[1] magnesium, allyl iodide, and ether give the compound C_3H_5MgI,C_3H_5I, that is, all the metal is not attacked in the action.

(4) *Importance of completing solution of the magnesium.*—It is not desirable to use a Grignard reagent containing an excess of the halide; calculated amounts of magnesium and halide should be used and the solution of the magnesium completed so far as possible. It should be noted that action between magnesium alkyl halide and excess of alkyl halide can take place with formation of hydrocarbon, $RMgBr+RBr=MgBr_2+R.R.$[2]

(5) *Substitution of other solvents for ether.*—It may be at once stated that ether is by far the most convenient solvent.

Brühl[3] shows that bromocamphor, for example, when mixed with benzene or xylene dissolves magnesium at elevated temperatures. Anisole,[4] amyl ether,[5] and toluene[6] have also been substituted for ethyl ether in certain reactions. Tschelinzeff[7] shows that, in the formation of Grignard's reagent, ether may be replaced by dimethylaniline. The reaction between dimethylaniline (2 mol.), ethyl iodide (1 mol.), and magnesium (1 atom) is assisted by the addition of a trace of iodine, but the magnesium does not dissolve so quickly as when ether is used. The method was used for the preparation of phenyl ethyl carbinol from benzaldehyde and of phenyl methyl ethyl carbinol from acetophenone. That tertiary amines do actually combine with magnesium organic compounds was subsequently shown by F. and L. Sachs,[8] who obtained, for example, the compound C_9H_7N,C_6H_5MgBr by the action of an ethereal solution of magnesium phenyl bromide on quinoline. Tschelinzeff,[9] arguing that tertiary amines form compounds of the type RRRN . RX, has accordingly devised the following modification in the preparation of the Grignard reagent, where a tertiary amine acts as a catalyser. Inert solvents, like benzene, toluene, xylene, hexane, light petroleum, and various terpene hydrocarbons may be used in place of ether if a few drops of a tertiary amine are added. In the case of benzene the following procedure is adopted: The mixture of anhydrous benzene, halogen compound magnesium, and a drop or two of dimethylaniline is heated to boiling until the beginning of the reaction is indicated by the appearance of white flakes; the reaction then proceeds without the application of external heat, and is finally completed by heating. The addition of a little iodine facilitates the starting of the action. In spite of the insolubility of the product, which separates as the type R . MgX, it is claimed that the action is much more energetic and often proceeds more quickly

[1] *Ann. Chim. Phys.*, 1901, **24**, 450; Houben, *Ber.*, 1903, **36**, 2897.
[2] Houben, *Ber.*, 1903, **36**, 3084.
[3] *Ibid.*, 1903, **36**, 668, 4272; 1904, **37**, 746; Malmgren, *ibid.*, 1903, **36**, 2608.
[4] Malmgren, *ibid.*, 1903, **36**, 2619; Houben, *ibid.*, 1905, **38**, 3019.
[5] Hibbert and Sudborough, *Trans. Chem. Soc.*, 1904, **85**, 933.
[6] Bodroux, *Compt. rend.*, 1904, **138**, 700.
[7] *Ber.*, 1904, **37**, 2081.
[8] *Ibid.*, 1904, **37**, 3088.
[9] *Ibid.*, 1904, **37**, 4534; *Chem. Zeit.*, 1906, **30**, 378.

than when ether is used. Further, in those cases where the reagent is formed with difficulty by the ordinary method, the higher temperature at which the Tschelinzeff reagent is formed would appear to be an advantage.

The author of this report has tried the Tschelinzeff method, with little success, however. In spite of what is claimed for it, the method, so far at least, has a theoretical interest only: it does not appear to have been applied at all, except in the very few cases mentioned by Tschelinzeff himself.

(6) *Acceleration of the formation of the reagent.*—Tissier and Grignard[1] found that, whilst alkyl bromides or iodides in ethereal solution as a rule readily interact with magnesium, the action with aryl halides is accelerated by heating or by the addition of a trace of iodine. A drop of methyl iodide[2] serves the same purpose; this may be used, for example, in the preparation of magnesium α-naphthyl bromide. Iodine and methyl iodide are the catalysers generally used. Monochlorides may not interact with magnesium and ether alone, but do so when a trace of iodine is added.[3] Aluminium chloride and hydriodic acid[4] may also be used as catalysers. An interpretation for the use of iodine in the formation of magnesium organic compounds from chlorides is advanced by Wohl,[5] namely,

$$2RCl + MgI_2 = 2RI + MgCl_2$$
$$2RI + 2Mg = 2RMgI$$
$$2RMgI + 2RCl = 2RMgCl + 2RI$$

In cases where interaction with the halide could not be effected by the usual methods, special devices have been employed. Thus, Ehrlich and Sachs[6] found that an ethereal solution of *p*-bromodimethylaniline is not acted on by magnesium even when the mixture is heated for several days in the presence of a little iodine. The interaction, however, was brought about as follows: The magnesium is covered with absolute ether and ethyl bromide added; the action soon becomes vigorous, as usual, and is then moderated by cooling the flask in ice-cold water; the supernatant liquid is poured off quickly from the magnesium and an ethereal solution of *p*-bromodimethylaniline is then added. By this treatment the magnesium had been rendered more active, and the magnesium compound desired was readily obtained by gentle warming. The fact, however, that the yield was far from quantitative, and that the product was necessarily mixed with a little magnesium ethyl bromide, occasioned v. Baeyer[7] to try other methods to make the magnesium active. This result is attained when the magnesium is coated with a thin layer of its iodide. Magnesium filings were heated in a round-bottomed flask over a free flame with constant shaking and half the weight of iodine gradually added. The temperature must not be so high as to cause the mass to melt. With 10 grams of magnesium this operation requires from 15 to 30 minutes. The product obtained must be protected carefully from moisture. This 'activirtes' magnesium was used by Baeyer himself for the preparation of the magnesium compounds of the iodoanilines and iododimethylanilines, and good results were also obtained by Gomberg and Cone[8] with diphenylbromomethane when other methods failed.

[1] *Compt. rend.*, 1901, **132**, 1182.
[2] Klages, *Ber.*, 1904, **37**, 1449.
[3] Compare Hesse, *ibid.*, 1906, **39**, 1146.
[4] Zelinsky, *J. Russ. Phys. Chem. Soc.*, 1903, **35**, 399.
[5] *Ber.*, 1906, **39**, 1952.
[6] *Ibid.*, 1903, **36**, 4296.
[7] *Ibid.*, 1905, **38**, 2759.
[8] *Ibid.*, 1906, **39**, 1467.

Kay and Perkin[1] find that commercial magnesium powder sometimes does not interact with *iso*propyl iodide in ethereal solution. When, however, the magnesium is left in contact with an ethereal solution of methyl iodide until the action is vigorous, then washed thoroughly with ether, and at once mixed with the ethereal solution of *iso*propyl iodide, the action proceeds satisfactorily.

(7) *Importance of preventing oxidation of the reagent.*—It should be noted that Bouveault and Bodroux have found that the Grignard reagent is acted on by oxygen to form primary alcohols or phenols, so that not only should the reagent be protected from moisture and carbon dioxide, but it should not be left unnecessarily long in contact with air before being applied. Sometimes, indeed, it is necessary to prepare the reagent in an atmosphere of hydrogen.[2]

Methods of applying the Grignard Reagent.

As a general rule the compound to be acted on is dissolved in anhydrous ether and the solution either added to the Grignard reagent or *vice versâ.* It is convenient to perform this operation by means of a siphon and to take precautions that moisture and carbon dioxide are excluded. As a rule, the action requires to be regulated, otherwise it may become too violent. When the addition is complete, sometimes the mixture is heated. Powdered ice is then gradually added, then mineral acid. The product of the action is generally in the ethereal solution.

The following description, taken at random, is typical. It is the method used by Ullmann and Münzhuber[3] for the preparation of triphenylcarbinol from methyl benzoate.

A mixture of magnesium (7·2 grams), freshly distilled bromobenzene (57·2 grams, 2·5 mol.), anhydrous ether (60–70 grams), and a trace of iodine is placed in a large round-bottomed flask provided with a reflux condenser and then gently warmed. As soon as the brownish liquid is decolorised and is boiling rapidly it is cooled by immersing the flask in ice-cold water; the action is regulated so that the boiling continues to be vigorous. After twenty minutes the bulk of the magnesium is dissolved; it is practically all gone after the boiling has been continued for half an hour longer. The flask containing the reagent is then placed in ice-cold water, and by means of a dropping-funnel a solution of 20 grams of methyl benzoate (freshly distilled) in an equal volume of anhydrous ether gradually added. The action is vigorous. After the addition of the ester the mixture is heated to boiling for about an hour, ice-cold water gradually added, and then dilute sulphuric acid. The ether is expelled from the ethereal solution and the product distilled in steam to remove unchanged bromobenzene and a small amount of diphenyl; the triphenylcarbinol remains in the flask. Yield of crude product, 33 grams (87 per cent.); when crystallised from alcohol 28 grams of pure product are obtained.

Of course this method of working cannot always be adopted. Water in some cases must not be added to the product of the action (compare Kipping's work on silicon compounds). Again, in the action of carbon dioxide and other gases on the Grignard reagent special methods have to

[1] *Trans. Chem. Soc.*, 1905, **87**, 1081.
[2] Tschitschibabin, *Ber.*, 1905, **38**, 561; Tschelinzeff, *ibid.*, 1906, **39**, 773.
[3] *Ibid.*, 1903, **36**, 406.

be used. Occasionally the temperature at which the reaction is conducted is maintained below 0°.[1] Sometimes ammonium chloride solution is used in place of mineral acid after the addition of ice;[2] thus in the preparation of phenylmethyltriazene by the action of magnesium methyl iodide the action of acid must be avoided, otherwise the very labile diazoamino-compound undergoes decomposition.[3]

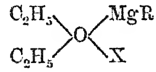
A perusal of the literature shows that it is often by no means immaterial whether the Grignard reagent is added to the compound to be acted on, or *vice versâ*. This is especially true when one deals with a compound presenting several points of attack for the Grignard reagent This aspect does not appear to have been fully recognised by a considerable number of investigators in this field. Further, the heating of the product obtained after mixing the Grignard reagent and substance acted on often has an important bearing on the result.

SECTION III.

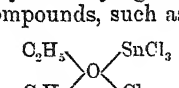
Theoretical.

The formation of Grignard's reagent was first represented[4] by an equation such as $CH_3I + Mg = CH_3MgI$, and it is convenient to interpret the various reactions as being due to the type R . MgX. The fact, however, that the reaction takes place with such ease in the presence of absolute ether suggested to Grignard himself[5] and to Blaise[6] that the ether is not simply a solvent in the ordinary sense, but is one of the necessary materials for the action. If the reaction product obtained from magnesium, ethyl iodide, and ether is heated under diminished pressure in a current of hydrogen, the residue contains the compound $C_2H_5MgI,(C_2H_5)_2O$, in which the ether is so firmly bound that it is only partially eliminated when the compound is heated under diminished pressure at 100°–125°. The compound $C_2H_5MgBr,(C_2H_5)_2O$ exhibits a similar stability towards heat.

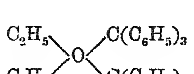
Whereas Grignard and Blaise at the time regarded the ether in these compounds as playing the rôle of ether of crystallisation, Baeyer and Villiger[7] formulate the compounds in question on the basis of the quadrivalency of oxygen, thus:



where R represents the alkyl or aryl group, and X the halogen atom. The existence of oxonium compounds, such as



and


(Gomberg)

[1] Kohler and Heritage, *Amer. Chem. J.*, 1905, **33**, 21.
[2] Tilden and Stokes, *Trans. Chem. Soc.*, 1905, **87**, 837.
[3] Dimroth, *Ber.*, 1903, **36**, 909; 1905, **38**, 670. Compare also Klages, *ibid.*, 1905, **38**, 2219.
[4] Grignard, *Compt. rend.*, 1901, **132**, 558.
[5] *Thèses sur les combinaisons organomagnésiennes mixtes et leurs applications à des synthèses* (Lyon, 1901).
[6] *Compt. rend.*, 1901, **132**, 839.
[7] *Ber.*, 1902, **35**, 1201.

is adduced in support of this view. Again, Ahrens and Stapler [1] formulate the compound obtained from ethylene dibromide thus :—

$$\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O<\!\!\begin{array}{l} Br \\ Mg\,.\,CH_2\,.\,CH_2Br \end{array}$$

The theoretical aspect of the Grignard reaction has been specially studied by Tschelinzeff. In an early paper [2] he concludes that the ether in the preparation of the Grignard reagent in the usual manner plays the part of a catalyser. He found that interaction between magnesium and alkyl halides took place in benzene solution only when the mixture was heated strongly. In the presence of a little ether (or of anisole), however, the reaction took place at a much lower temperature, at which no action occurred when the ether (or anisole) was absent ; the action was very slow, requiring from one to two days for its completion. The white mass, which separated contained no ether, exhibited all the ordinary reactions of magnesium organic compounds, and was formed in considerable yield. The point is that this effect was produced by means of a small amount of ether.

Reference has already been made in Section II. to Tschelinzeff's use of tertiary amines as catalytic agents. In a subsequent communication,[3] Tschelinzeff describes thermochemical experiments, in which the heat evolved by the action of ether on the ether-free compounds obtained by this catalytic method was measured :

$$RMgI+\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O=\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O<\!\!\begin{array}{l} MgR \\ I \end{array}+T$$

The formula of Baeyer and Villiger is preferred to

$$\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O<\!\!\begin{array}{l} MgX \\ R \end{array}\qquad\text{(Grignard)}$$

or to the representation from Werner's standpoint

$$\left(\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O\ .\ .\ .\ MgR\right)X$$ [4]

Although ether is not readily eliminated from the complex

$$\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O<\!\!\begin{array}{l} MgR \\ X \end{array}$$

it is possible to study the heat effect produced by the change

$$(C_2H_5)_2O+RMgX=\begin{array}{l} C_2H_5 \\ C_2H_5 \end{array}\!\!>O<\!\!\begin{array}{l} MgR \\ X \end{array}$$

since it is possible to prepare the 'individual' magnesium compounds free from ether. Tschelinzeff concludes that in the preparation of the Grignard reagent by the ordinary method there are two distinct reactions :

[1] *Ber.*, 1905, **38**, 3259. [2] *Ibid.*, 1904, **37**, 4534. [3] *Ibid.*, 1905, **38**, 3664.
[4] *Annalen*, 1902, **322**, 261. The theory of the Grignard reagent is also discussed by Abegg, *Ber.*, 1905, **38**, 4112.

(1) the formation of the magnesium alkyl (or aryl) halide, and (2) the transformation of this into an ether complex.

Tschelinzeff[1] next points out that, after all, those ether complexes were characterised by Grignard and Blaise subsequently to heating the Grignard reagent under diminished pressure. It is not justifiable to assume, as is generally done, that those same complexes actually exist under the conditions which obtain when the Grignard reagent is made in the usual manner. Tschelinzeff, in his previous paper (*loc. cit.*), although actually showing that at least one ether complex is formed, does not prove that the formation of additional complexes is impossible. Now Zelinsky[2] has obtained the compound $MgI_2,2(C_2H_5)_2O$, and Tschelinzeff the compound $MgI_2,4(C_2H_5)_2O$. The analogy is accordingly drawn between the formulæ

$$(C_2H_5)_2OI \cdot Mg \cdot I(C_2H_5)_2O \text{ and } R \cdot Mg \cdot I(C_2H_5)_2O$$

Now, since the magnesium iodide complex

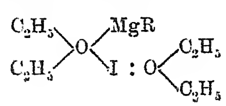
$$[(C_2H_5)_2O]_2I \cdot Mg \cdot I[(C_2H_5)_2O]_2$$

is known, the question naturally suggested itself as to the possibility of analogous ether complexes of the type $R \cdot Mg \cdot I[(C_2H_5)_2O]_2$. The compounds

$$C_3H_7MgI,2(C_2H_5)_2O \text{ and } C_5H_{11}MgI,2(C_2H_5)_2O$$

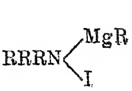
were accordingly isolated.

These results, based on analytical and thermochemical experiments, prove conclusively, according to Tschelinzeff, that in the preparation of magnesium organic compounds by Grignard's method one obtains ether complexes with two molecules of ether, for which the formulation



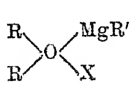
is suggested.[3]

Tschelinzeff[4] also shows that the 'individual' magnesium organic compounds are also capable of forming complexes with tertiary amines, thus :—



These aminates are analogous to monoetherates. No complexes have yet been described analogous to dietherates.

The question of the constitution of the oxonium compounds formed in the preparation of the Grignard reagent by the ordinary method, is still however under discussion. Tschelinzeff[5] points out that if Baeyer's formulation



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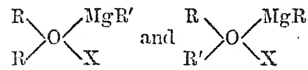
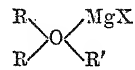
[1] *Ber.*, 1906, **39**, 773.
[2] *J. Russ. Phys. Chem. Soc.*, 1903, **35**, 399.
[3] Compare also Tschelinzeff, *Ber.*, 1906, **39**, 1674, 1682, 1686.
[4] *Ibid.*, 1907, **40**, 1487. [5] *Compt. rend.*, 1907, **144**, 90.

is accepted, two isomerides are possible, namely,



whereas if Grignard's formulation



is correct, no isomerism is possible. Tschelinzeff claims to have established the existence of isomerides. Grignard,[1] however, maintains that his formula permits of the conception of isomerides, and regards it as more plausible than Baeyer's.

Investigation of the Fauna and Flora of the Trias of the British Isles.—Fifth Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. J. LOMAS (*Secretary*), Professor W. W. WATTS, Professor P. F. KENDALL, Professor A. C. SEWARD, *and* Messrs. H. C. BEASLEY, E. T. NEWTON, W. A. E. USSHER, *and* Dr. A. SMITH WOODWARD. (*Drawn up by the Secretary.*)

[PLATES II. AND III.]

THE increased interest now being taken in the Trias rocks, largely a result of the Committee's work, has led to some very interesting discoveries during the past year. A rich assemblage of fossils has been described from the Lower Keuper of Bromsgrove by Mr. L. J. Wills, a new Dinosaurian reptile has been described by Dr. A. Smith Woodward from Lossiemouth, Elgin, and in the present report Dr. Smith Woodward contributes a paper on a mandible of *Labyrinthodon leptognathus.* The great find of footprints at Storeton in 1906 is likely to be repeated in 1907, for in the autumn the footprint bed will be again worked and a larger surface will be exposed.

There is a considerable amount of material in hand which requires to be reported on by specialists, and if the Committee is reappointed it hopes to accomplish this work in time for next year's Report.

On a Mandible of Labyrinthodon leptognathus, *Owen.* *By* A. SMITH WOODWARD, *LL.D., F.R.S.*

Mr. S. S. Stanley, F.G.S., has recently obtained from the Lower Keuper sandstone of Cubbington Heath, near Leamington, the greater part of a mandible of *Labyrinthodon leptognathus,* which he has generously presented to the British Museum. The specimen is interesting, not only on account of the rarity of such fossils in the English Keuper, but also as showing more clearly than heretofore the characters of the lower jaw

[1] *Bull. Soc. Chim.*, 1907 [iv], 1, 255.

in the species to which it belongs. It is, moreover, valuable as exhibiting the anterior limits of the angular and splenial bones.

Various drawings of the fossil, of one-half the natural size, are given in the accompanying Plate II. The articular end of the mandible is lacking on both sides, but the right ramus is complete so far back as the position of the internal vacuity (fig. 3, *v.*). Each ramus is more or less laterally compressed, being twice as deep as broad near the hinder end of the tooth-bearing portion (fig. 4), and gradually tapering towards the short symphysis, which is comparatively weak and depressed (figs. 1, 5). It is hollow at least as far forwards as the fractured end of the fossil on the left side. The dentary bone (fig. 2, *d.*) forms the greater part of the outer face of the mandibular ramus so far as preserved, but its precise extent in the symphysial region is uncertain. Its outer surface is smooth and slightly convex, while its oral border bears a single close series of slender conical teeth, which are nearly uniform in size for the greater part of its length, but diminish both at the hinder end and at the side of the symphysis where they flank the enlarged inner teeth. The angular bone (*ag.*) is shown on the outer face to taper rapidly in front beneath the hinder part of the dentary, where it is ornamented with a few coarse ridges, which radiate forwards from a point situated postero-inferiorly to the piece of fossil preserved. The long and narrow bone (*id.*) which forms the lower portion of the outer face of the mandibular ramus in front of the angular just described, may be appropriately named infradentary. Its outer face bulges rather more than the dentary, and is only faintly marked with stout reticulating ridges until it approaches the symphysis, where it seems to spread over the flattened lower face of the jaw and its ornamentation becomes conspicuous. This lower face (fig. 5) exhibits the jagged median suture in which the two rami of the mandible are firmly united, but it does not clearly show any other sutural lines. The upper part of the inner face of the mandibular ramus is formed by a long and narrow smooth splenial element (fig. 3, *spl.*), which terminates in front just before reaching the symphysis. During the greater part of its length it rises into a low parapet on the inner edge of the rather wide alveolar groove in which the teeth are fixed at the outer edge. Below the narrow splenial there are two deeper laminæ of bone (*x*, *y*), separated by a very oblique suture, which is inclined downwards and forwards. These bones are quite smooth where they form the inner face of the jaw, but exhibit an ornament of stout reticulating ridges where they bend into the lower face, and may be continuous respectively with the angular and infradentary elements already described. When viewed from above (fig. 1) and behind (fig. 6) the symphysis distinctly exhibits the jagged median suture, but its precise constitution is not clear. It is impressed behind by a pair of slit-like hollows (*h.*), which may have formed the insertion for the genio-hyoid muscles. Its flattened upper or oral face is excavated on each side by a large shallow oval pit (*l.*), with the long axis transverse, just internal to the row of marginal teeth. In the front part of each pit are implanted two relatively large conical teeth which would probably be shed alternately. A second pair of diminutive oval pits occurs just behind, containing in the fossil two and three small conical teeth respectively. Nearly all the teeth are partially obscured by the sandy matrix which has necessarily been left to strengthen such fragile prominences; but they are seen to be nearly round in section, with a very

small pulp-cavity, and their typically labyrinthic structure is shown, not only in cross-sections, but also in the longitudinal striation of their exterior.

A comparison of this new fossil with the fragmentary portions of mandible from Coton End, Warwick, originally described by Owen[1] under the name of *Labyrinthodon leptognathus*, can leave no doubt as to its specific identity. Its correct generic name, however, still remains to be determined, for *Labyrinthodon* is an undefined term without exact meaning. I am inclined to believe that the specimen will eventually prove to belong to *Capitosaurus*, which has already been discovered in the English Keuper,[2] and seems to have been widely distributed in the Trias; but the piece of rostrum associated by Owen with the mandibular fragments is insufficient for generic determination, and the undoubted mandible of *Capitosaurus* is still too imperfectly known for comparison.[3] The precise name of the fossil, however, is of secondary importance. Its chief value consists in the manner in which it confirms recent conclusions as to the complex structure of the mandibular ramus in the Labyrinthodonts,[4] and helps to connect these early Amphibians with the Palæozoic Crossopterygian fishes.

Explanation of Plate II.

Labyrinthodon leptognathus, Owen: incomplete mandible, one-half nat. size.—Lower Keuper; Cubbington Heath, Leamington. [British Museum, No. R. 3493.]

Fig. 1. Upper view.
Fig. 2. Outer view of right mandibular ramus.
Fig. 3. Inner view of the same.
Fig. 4. Transverse section of right mandibular ramus at hinder end of fossil, showing extent of internal cavity.
Fig. 5. Lower view of symphysis.
Fig. 6. Back or inner view of symphysis.

ag., angular; *d.*, dentary; *h.*, hollow for insertion of muscle (genio-hyoid?); *id.*, infradentary; *l.*, shallow fossa for insertion of laniary teeth; *spl.*, splenial; *v.*, position of inner vacuity; *x*, supposed inner plate of angular; *y*, supposed inner plate of infradentary.

Report on Footprints from the Trias. Part V. By H. C. Beasley.

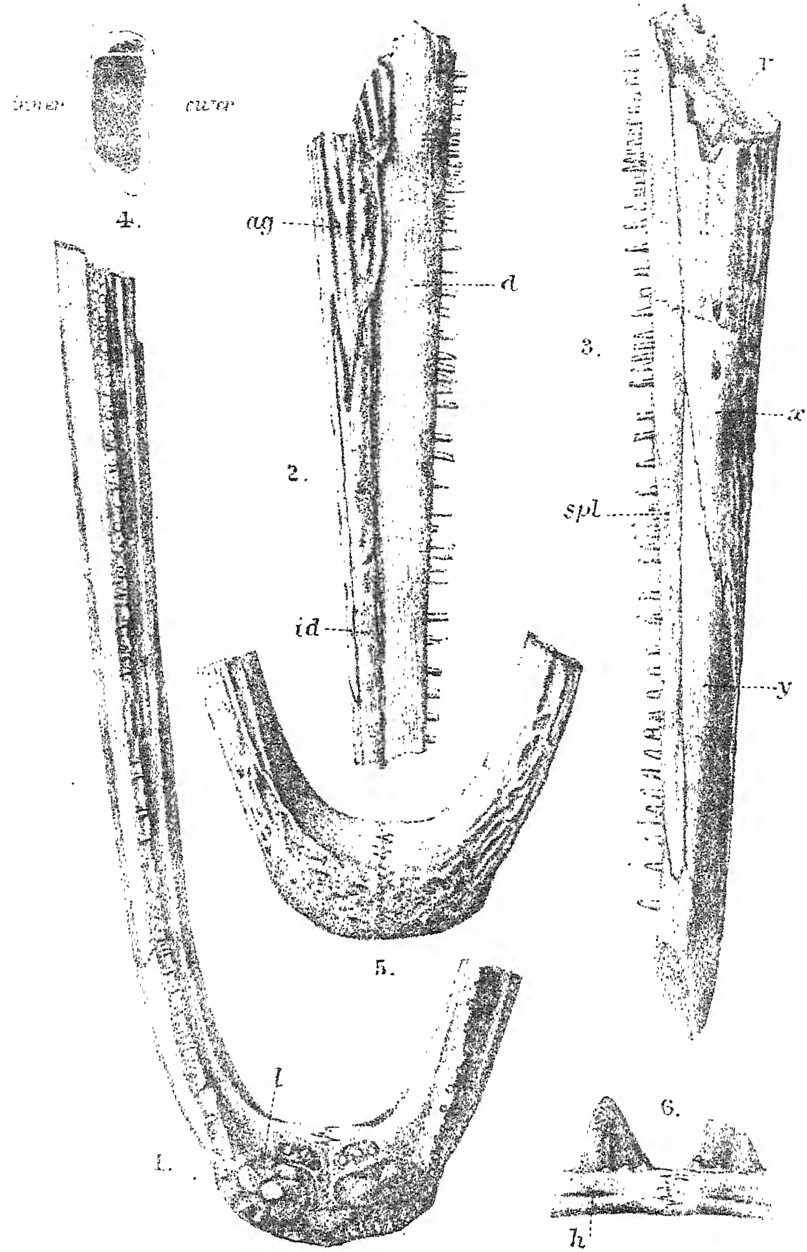
Since the York meeting an opportunity has been afforded of examining under very favourable conditions a quantity of material from the Storeton Quarries. Owing to the generous response of Mr. Wells, the quarry owner, to a suggestion of the Liverpool Geological Society, the footprint-bearing blocks were raised with care and allowed to weather naturally, and so the adherent clay was removed without injury to the smaller markings. Fortunately the portion of the bed cut through had a very smooth surface and was free from desiccation cracks.

[1] R. Owen, *Trans. Geol. Soc.* [2], vol. vi. (1842), p. 516, pl. xliv., figs. 7–9.

[2] A. S. Woodward, *Proc. Zool. Soc.*, 1904, vol. ii. p. 170, pl. xi. (*Capitosaurus stantonensis*, from Lower Keuper, Stanton, North Staffordshire).

[3] F. A. Quenstedt, *Die Mastodonsaurier* (1850), p. 16, pl. ii., fig. 2; H. von Meyer, *Palæontographica*, vol. vi. (1858), p. 228, pl. xxviii., fig. 1; and K. A. von Zittel, *Handb. Palæont.*, vol. iii. (1888), p. 404, fig. 396.

[4] E. B. Branson, 'Structure and Relationships of American Labyrinthodontidæ,' *Journ. Geology*, vol. xiii. (1905), pp. 568–610, especially figs. 4, 10, and 13.



LABYRINTHODON LEPTOGNATHUS, Owen.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

The actual area exposed was about 40 feet by 50 feet, and from this between twenty and thirty footprint-bearing blocks were raised, many of them over 6 feet square. The examination of these has resulted in some addition to our previous knowledge, and the more important features may well be recorded.

The prints are found at the extreme north end of the south quarry in three beds. The upper bed is much cut up by desiccation cracks, and the prints are not very well preserved; only a few rather large Cheirotherium (A 1) prints with the digits widely spread, and not at all clearly impressed, and a few Rhynchosauroid prints were found. It would seem that the conditions were unfavourable to the production of good prints; however that may be, very few slabs seemed worth retaining by the quarrymen.

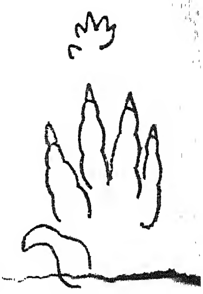
The middle bed presented an extremely fine and smooth surface for a sandstone, was free from cracks and distortion of any kind; and from this bed the greater number of prints were obtained.

The lowest of the three yielded some small prints, mostly Rhynchosauroid, on an uneven and coarse surface.

Cheirotheroid Forms.—A 1 =*Cheirotherium stortonense* was well represented, and the fact, hitherto rather uncertain, that the digits of the manus terminated in nails was distinctly proved by several examples. The small tubercles described by Professor Williamson as covering the sole of the foot in a specimen from Daresbury were very distinctly marked on most of the prints.

Owing to the large size of the slabs it was possible to examine and compare a great number of continuous series of prints both of this and other forms. The linear arrangement of the prints of this form and the parallelism of the axis of the foot with the line of movement, as well as the nearness of the right and left prints to the median line previously observed, were very generally present.

A 4, described in the report, Part IV., presented at the York meeting from some imperfect specimens, has been largely represented in the present find, and some modifications and additions to the description given will be necessary. Instead of the pes being like that of A 1 the IV. digit is found on all the prints to be much shorter in proportion to the other digits than in A 1. The V. digit, which is smaller than in A 1, is about the same proportionate size as in A 2. No. IV., though short, is generally well developed and stout, and has a long and sharp nail; No. 1, which is somewhat longer than IV., is slender and weakly impressed. The manus has five digits, but V. is not generally so clearly shown as the others; it is rather in the rear of the others in a corresponding position to the same digit of the pes. The type is a series in the Zoology Museum of the Liverpool University. They are also present on the British Museum Slab, R. 3483.


Right Pes and Manus. A 4. $\frac{1}{6}$.

As pointed out by Mr. Lomas in his description of the slab in the Museum of the Liverpool University, the axes of the hind feet instead of being parallel to the line of movement point outwards at a considerable angle. This is the case with all the prints that have been examined, and, taken in connection with the small size of the manus and the fact that it (the manus) made no deeper impression than the much larger surface of

the pes, is suggestive of different functions for the pes and manus, or at any rate in the part taken by each in locomotion and support of the body.

All the prints are well covered with tubercles. On the pes they vary from 1·5 mm. to 2 mm. in diameter, and those on the manus something less than 1 mm. Where the feet have sunk deeply into the mud we have indications of the tubercles, not only on the soles, but on the sides of the toes.

These prints are found on about half a dozen of the slabs raised, and in every case they correspond in form and size, which suggests the possibility of their having been made by one individual.

There are also two pairs of prints on a slab in the Liverpool Museum obtained many years ago (locality uncertain), and in the Warrington Museum there is a similar slab (from Storeton), with again two pairs of prints. However, in this case the print of the pes is about an inch longer than those of the present find. The Warrington slab certainly cannot have been acquired since 1874, and probably dates back to before 1856. As at either of those dates the workings were carried on at a considerable distance from the present ones, this, together with the slight difference in size, will warrant our treating the difference from A 1 as specific, and not merely as the result of some individual deformity.

No other Cheirotheroid forms have been observed, but a great variety of forms of prints that must be included under A 1 has been presented. A notable instance is shown on a large slab acquired by the Owens College Museum, Manchester, which has a series of four pairs of a large-sized print of A 1, the length of the pes being nearly 10 inches, and the digits remarkably stout and fleshy. On the same slab are two prints of a pes of very slightly smaller size, but much more slender proportions. The information at present available is, however, insufficient to determine whether these differences are due to age or individual peculiarities, or specific difference in the animals. The differences are very striking, and cannot be ignored, whatever their cause may have been.

Rhynchosauroid forms.—Although a number of these forms are present on these slabs, there is still a difficulty in differentiating the fore and hind feet, so few can be traced in regular series. In one large form of D 1, about 4 cm. long, it was possible to measure the length of stride. The distance between two prints on the same side was 26 cm., and between the lines of right and left tracks apparently 7 cm.

On a slab, probably from the lowest of the three beds now in the Museum of the Liverpool University, there is a short series and a number of detached prints of a small Rhynchosauroid form, which we shall distinguish as D 7. It is only an inch in length: the V. ~~digit is very much~~ shorter than II., III., and IV. and points somewhat backwards, *i.e.*, it makes an angle greater than 90° with the axis of the foot. The other digits are generally widely spread, but sometimes II./IV. lie close together and quite parallel; IV. is the largest, I. is short and divergent, but not to the extent of V. Each seems to be terminated by a sharp nail; the digits are usually straight, but are at other times decidedly curved.

Left Pes or Manus. D 7. ½.

The length of stride between two prints on same side is 13 cm.; distance between lines of right and left tracks 7 cm. The track was very

irregular, and the length of the stride varied a good deal, and the figures given are only an approximate average.

These prints, although rather larger, agree fairly well in form with the pes of E,[1] except that in E there is no trace of a V. digit, whereas on these the V. is strongly marked. With E there is almost always a small manus present on the inner side of the pes; no trace of a manus has been seen with these. The form seems very generally distributed, but it has been very difficult to find a series at all complete.

It has some affinity with O from Hollington,[2] but there are differences which show it to be an entirely distinct form.

The prints even in the same series vary a good deal in form, and at first sight might not be regarded as connected; but a little careful examination shows them to be the same foot. The differences are very generally caused by the straight or curved positions of the digits when put down.

A print was described in the 1904 Report as F 2 from one fairly perfect print from Storeton, but it had not been seen in series. On the slabs now described there are several series of prints that appear closely allied to this, which will be distinguished as F 3. This form differs in having the claws less curved, and the protuberance at the base of the claw is less pronounced. The pes is, if anything, rather smaller than the manus, and the claw not quite so strong, and in both the digits are longer than in F 2.

The prints of the pes and manus were frequently superimposed, giving rise to a long, narrow print with short digits. In one series nine of these followed each other without any separation of the prints being visible, but in another series they were found, as the track was followed, to separate into two clearly defined footprints. Closely associated with these, prints were noticed in which the digits terminated by circular discs: these had been also noticed on some prints at Runcorn; there is little doubt these are caused by a movement of the claw, and not to any abnormal termination to the digit. This is probably also the case with some of the Rhynchosauroid prints that show a thickening of the end of the digit, and no visible claw.

As there are certainly very marked differences in this print from any previously referred to, it is described as F 3. A broad print with the digits about half the total length of the print, five digits, the middle being the longest, each terminated by a powerful claw, less curved than F 2, and generally distinctly marked.

Right Manus. F 3. $\frac{1}{2}$.

Manus.	Length of print	3·5 cm.
	Length of middle digit	1·5 „
	Breadth of print	3 „
	Distance from one print to another of same foot	20 „
	Distance from right and left tracks about .	6 „

[1] *Brit. Assoc. Rep.*, Cambridge, 1904.
[2] *Ibid.*, Part IV., 1906, York.

The best series is on the square slab now in the British Museum (R. 3483), which we may take as the type (Plate III.); but they were also present on other slabs of the present find.

The longer slab in the British Museum, R. 3484, has a number of prints of probably the same foot, but differing slightly to size, and occasionally in minor details.

Traces of a footprint that seems to be of an entirely different type from any hitherto recorded from Storeton have been seen, but they are too ill-defined to warrant detailed description in the absence of more perfect examples. As far as can at present be made out, they are about 6 cm. broad by 4 cm. long, and consist of four slender digits. There are indications in every case of a high, roughly semicircular ridge of mud having been raised in the rear of the print such as it would seem hardly probable would be raised by the pressure of the slender toes alone unless the feet were webbed, of which so far we have no indication.

Examples may be seen on the slab in the British Museum, R. 3483.

Besides the vertebrate prints, several of the slabs show tracks of invertebrates, worms, and possibly gastropods, varying in width from 2 mm. to 15 mm.

The vast number and variety of markings preserved afford material for investigation, which, it is hoped, will be carried on by the palæontologists and others of the various towns and cities in whose institutions the specimens are now deposited. Among these are:—

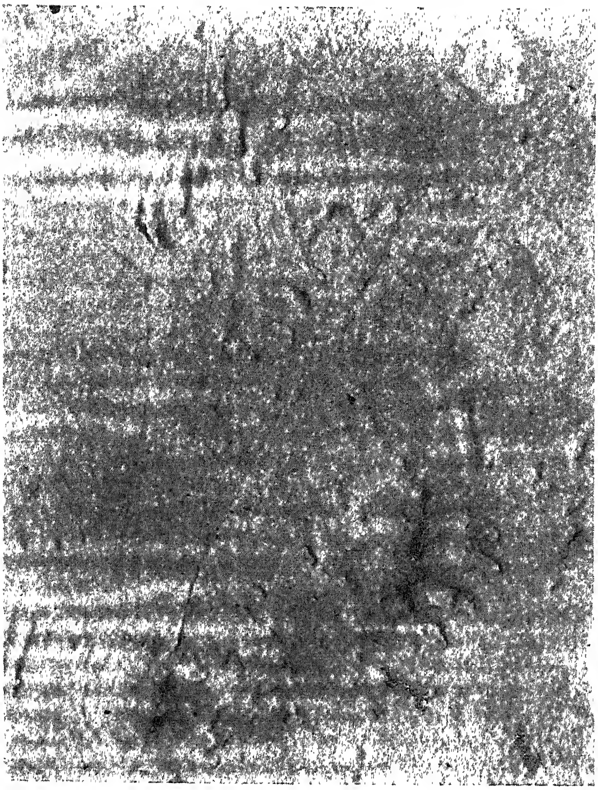
British Museum, Natural History.
Hull Municipal Museum.
Leeds Library and Philosophical Society.
Leeds University.
Bolton.
Birkenhead Corporation.
Manchester, Owens College.
Liverpool University.
Others have been deposited in private collections.

No attempt has been made to attach generic or specific names to the various forms, as it seems advisable to await further investigation before taking this step. It is hoped that those interested in the fauna of the Trias will find the plan adopted sufficient for purposes of identification.

On a Footprint Slab in the Museum of Zoology, University of Liverpool. *By* J. Lomas, *A.R.C.S., F.G.S.*

A large slab of sandstone from Storeton, presented to the Liverpool University by Mr. C. Wells, J.P., has afforded exceptional opportunities for the examination of a group of footprints described by Mr. H. C. Beasley as A 4.

The large size of the slab—over 11 feet—gives a track containing fifteen impressions made by the same individual, four right pes, four left pes, four left manus, and three right manus. The prints are exceptionally perfect, in low relief, and details are shown which have not hitherto been seen.



Portion of slab from Storeton, with footprints of tpye F 3.

Photograph by Mr. C. B. TRAVIS, Liverpool.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

The accompanying illustration drawn to scale shows a portion of the track. The line marking the centre of the track not only touches the bases of the V. digit of the pes—the swollen one—but runs almost along the axes of I., the smallest digit. The axis of each foot measured along the middle digit is turned outwards from the central line at about 30°, so the animal walked with its feet splayed outwards to each other at an angle of 60°.

It will be noticed, too, that the weight mainly rested on the outer toes, for the inner ones are lightly impressed, while the outer ones are swollen and fleshy, and make deeper impressions. This would no doubt give greater stability to the animal on walking over mud or loose sand. The length of the stride is remarkably uniform, only varying from 2 feet $7\frac{1}{2}$ inches to 2 feet 8 inches.

The manus, on the other hand, is not so regularly disposed. The right manus in each case is from $1\frac{1}{2}$ inch to 3 inches in advance of the pes, while the left is superimposed on the terminal phalange or nail of the pes. They all trend outwards, corresponding roughly with the direction of the pes.

Measurements of the pes show that the axes of the digits converge towards the base of the V. digit. Reckoning from this point, the length of the various digits are as follows: I., 5 inches; II., $6\frac{3}{4}$ inches; III., 7 inches; IV., $5\frac{3}{16}$ inches; V., $3\frac{3}{8}$ inches. With the exception of V., which has two, the toes have three joints, with well-marked, fleshy pads, and at their bases other pads are seen which fuse together to form a continuous ridge. In these respects it is remarkably like the human hand, but there is no sign of the fleshy pad which joins the little finger with the wrist in the latter.

Each toe is terminated by a claw, and this extends beyond the limits of the digits to distances varying from half an inch to an inch. It would seem that the animal had the power of extending and retracting its claws, for sometimes they appear as round or triangular punctures made by a pointed object, and at other times as long oval markings, such as would be made if the claw were extended The tubercles described by Mr. Beasley as occurring on the under-surface of the foot extend, not only over the fleshy pads, but also in the hollow or palmar surfaces.

Details of the manus are not easy to determine owing to the smaller size and the very faint impressions left for examination. The second, third, and fourth fingers are always close together, while the first and the fifth usually appear as small indistinct markings, sometimes quite isolated from the others. In most cases they are absent altogether, and until the present exceptional find it was regarded as a three-fingered hand. In some slabs showing typical pes of this kind the manus is entirely wanting. This and other considerations lead one to surmise that the manus played a very subordinate part in progression. It may be that

the animal walked erect on the pes, and only used the manus to steady itself when bending down to drink or feed. The palmar surface of the hand is seldom seen, but when present it is, as well as the fingers, covered with scaly tubercles. The digits are terminated by small triangular claws.

On the same slab there are the tracks of two other Cheirotheroid forms corresponding with the type of A 1. The surface, too, is dotted with numerous Rhynchosauroid forms, and it is interesting to note that the slender digits of these animals show fine tubercular skin markings similar to, but smaller than, the Cheirotheroids.

The surface of this slab is covered with a smooth ferruginous scale which has taken the cast of the moulds in the underlying clay in a most perfect form.

An examination of the scale shows it to be composed of sand grains cemented by iron oxide. The iron has no doubt percolated in solution through the overlying sandstone as far as the impervious clay band on which the footprints were made. The beds below are even now much drier than those above. Specimens of the sandstones have been examined at intervals of 10 feet throughout the depth of the quarry (110 feet), and it is found that those above the footprint bed, 60 feet from the surface, contain, as a rule, less felspar and mica than those below this horizon. Secondary crystallisation on the quartz grains is also more common in the upper series than the lower. They all contain small quantities of other minerals such as zircon, tourmaline, anatase, rutile, kyanite, staurolite, chert, and numerous black grains of uncertain composition; but in the scale overlying the clay there is a concentration of these minerals. Zircon especially is very abundant in very minute crystals.

It is noteworthy that while numerous samples have been fractionated with heavy fluids, not a single grain of garnet has been obtained. The overlying boulder clay and the sands of the Mersey contain an abundance of this mineral. The same remark applies to all the Triassic rocks I have examined in the Liverpool district, and in this respect they differ from the Trias in the South of England examined by Mr. H. H. Thomas.[1]

The Flora and Fauna of the Trias (Keuper only) in Leicestershire, with some Notes on that of the surrounding counties. By A. R. HORWOOD, *Sub-Curator, Leicester Corporation Museum.*

In Leicestershire the principal fossiliferous horizon of the Keuper is the Upper Keuper sandstone.

From that horizon there have been collected or recorded plant-remains, Annelid and Crustacean tracks, &c., *Estheria minuta* (Alberti), spines and teeth of *Acrodus keuperinus* (M. and S.), *Acrodus* (?) *minimus*, Ag., *Acrodus* spp., *Gyrolepis quenstedti* (Dames), *Colobodus frequens* (Dames), a footmark of (?) *Labyrinthodon*, bones of Amphibia, &c., bones of Reptiles. The best exposure at the present time is at Shoulder-of-Mutton Hill, in the railway cutting (Leicester and Burton line).

The flora is suggestive of land conditions, but the plant-remains are imperfect, and may well be compared to those of the Upper Carboniferous or Permian formations.

The fauna suggests an inland sea or possibly a salt lake.

[1] *Quart. Journ. Geol. Soc.*, November 1902, p. 620.

The overlying grey and red marls and the red marls below the sandstones have furnished no traces of past life in the Trias of Leicestershire, except 'casts of the spreading leaves' of *Voltzia* sp., a Conifer, discovered by Mr. W. J. Harrison, F.G.S. At this horizon the deposits are highly saliferous, containing gypsum and pseudomorphs of salt crystals. The whole formation is also charged with sulphate of baryta and sulphate and carbonate of lime, the water-supply obtained from this horizon possessing a high percentage of these substances. It is from the Lower Keuper (Waterstones) that water is principally obtained locally and utilised.

In the Tea-green Marls the fauna—no plant-remains having been discovered so far—approaches that of the Sandstone beds at the base of the Upper Keuper. It was in these that Mr. Harrison was also fortunate enough to discover the wing of an insect; but he informed the writer that it perished soon after exposure to the atmosphere.

The fauna here appears to indicate more lacustrine conditions, as the only fish that is abundant belongs to a genus probably Semionotoid or perhaps Palæoniscoid. Selenite and salt crystals occur at this horizon, and ripple-marks and rain-pittings are also met with.

The marls pass up insensibly into the Rhætic beds above, being at one time considered their lowest member. The best palæontological break, however, occurs above the Tea-green Marls, where physical conditions again change.

The Flora and Fauna of the Keuper in Leicestershire.

Upper Keuper Sandstone.

* The numbers in parenthesis refer to the bibliography page.
† Specimens marked thus are represented in the Leicester Corporation Museum (= L.M.)
‡ This *nomen nudum* was invented in 1849 for specimens which are probably nothing more than inorganic casts of tracks and galleries, the work of Worms or Crustacea.
§ Recorded in 13th Report, Leicester Museum, as *Nemacanthus*.

Genera and Species	Locality	Reference	Remarks
PLANTÆ.			
THALLOPHYTA.			
Algæ	Leicester (well-boring)	* (1856)[1] pp. 371, 373	Fig. 1 (a section) includes a thin 'black carbonaceous band, with supposed Algæ.'
PTERIDOPHYTA EQUISETALES.			
Equisetites sp. . .	Shoulder-of-Mutton Hill railway cutting	*Ibid.*, p. 373 . .	—
(?) " " . .	" " , "	† L.M.	No. $\frac{1893}{119}$. Several casts of the stem of an equisetaceous plant, but exhibiting no distinct leaf-sheath.
(?) " " . .	Westcotes . . .	† L.M. . .	No. $\frac{1907}{1}$. This specimen is probably equisetaceous, but the leaf-sheath is indistinct.
LYCOPODIALES.			
(?) Lycopodiaceous rootlet cf. *Stigmarites* sp.	Dane Hills . . .	† L.M.	No. Z 5. A fragment bearing no rootlet scars, but dichotomising, as in Stigmarian rootlets or rhizomes.
CONIFERÆ.			
Voltzia, sp. . . .	Shoulder-of-Mutton Hill railway cutting	(1856)[1] p. 373 . .	—
(?) " "	Leicester . . .	(1904) p. 8 and (1905)[2] p. 14 (reprint)	B.M. 24, 190, labelled *Gorgonia keuperi*.

The Flora and Fauna of the Keuper in Leicestershire—continued.

Genera and Species	Locality	Reference	Remarks
PLANTÆ—*cont.*			
INCERTÆ SEDIS.			
Plant remains	Leicester	† L.M.	See MS. 'Donation Book,' Leicester Museum, 1855 pp. 79, 138.
(Under *Echinostachys oblongus*, Brongn.)	"	† L.M. and (1856)[1] p. 373	The specimen No. $\frac{1893}{156}$ exhibits no definite characters, and is associated with worm-tracks.
INCERTÆ SEDIS.			
Cast of stem	"	† L.M.	No. $\frac{1893}{150}$. This specimen exhibits no characters, but it may be equisetaceous.
Stem-fragments	"	† L.M.	No. $\frac{1893}{155}$ labelled casts of *Gorgonia* or Fucoids, but certainly neither.
INVERTEBRATA.			
ANNELIDA OR CRUSTACEA			
'Cololitic remains of Annelida'	Well-boring, Leicester, and Shoulder-of-Mutton Hill railway cutting	(1856)[1] p. 369. † L. M.	No. $\frac{1893}{154}$ (labelled *Gorgonia keuperi*.‡ No. $\frac{1893}{156}$ ('casts of *Gorgonia* or *Echinostachys oblongus*')
'and casts of their tubes'	" " "	*Ibid.*, p. 373	No. $\frac{1893}{161}$ 'casts of probable worm-tracks or Fucoids.' The second, in so far as *Echinostachys* is concerned, may be partly referable to some plant; but the *Gorgonia* is only, like the other specimens, the work of worms or crustacea.
—	—	—	No. $\frac{1893}{155}$, *supra*, may also be in part referable to the same agency.
Worm-tracks, worm-tubes, and cololitic remains of marine worms.	Dane Hills	(1875) p. 45	—
CRUSTACEA.			
Estheria minuta (Alberti).	Belgrave	† L.M.	See MS. 'Donation Book' of Leicester Museum, 1851.
" "	Leicester (well-shafts)	(1856)[1] p. 369	—
" "	Shoulder-of-Mutton Hill railway cutting	*Ibid.*, p. 373; (1872) p. 33; (1862) p. 63	—
" "	Dane Hills	† L.M. (1875), p. 45	—
" "	Aylestone Road	(1893) pp. 99, 153	—
" "	—	† L.M.	No. $\frac{1890}{313}$.
VERTEBRATA.			
PISCES.			
Acrodus keuperinus, (M. & S.)	Shoulder-of-Mutton Hill	† L.M.	Fine dorsal fin-spine collected by Mr. W. J. Harrison
" " "	" " "	† L.M.	Teeth, collected by W. J Harrison.
" " "	New Parks	† L.M.	$\frac{1904}{2}$ Portions of spines.
" " "	Dane Hills	† L.M.	—
" " "	Aylestone Road	(1893) pp. 99, 106	—
" " "	—	† L.M.	No. $\frac{1890}{314}$.

Upper Keuper Sandstone, Leicestershire—continued.

Genera and Species	Locality	Reference	Remarks
VERTEBRATA—*cont.*			
Pisces—*cont.*			
(?) *Acrodus keuperinus* (M. & S.)	Shoulder-of-Mutton Hill, Leicester	(1877) p. 33. † L.M. .	Recorded as '*Acrodus* teeth.' $\frac{1893}{226}$ recorded as *Hybodus* teeth.
(?) " "	Leicester. Shoulder-of-Mutton Hill railway cutting	(1856)¹ p. 373 . .	'Teeth of Placoid fishes.'
(?) " "	" " "	*Ibid.*, † L.M. . .	$\frac{1893}{229}$ 'Ichthyodorulites.' §
(?) " "	" " "	† L.M., 'Report Leicester Museum,' 1873, p. 15	'Spines, teeth, (and scales) of *Acrodus*' collected by W. J. Harrison and J. E. Elgood.
(?) *Acrodus minimus*, Ag.	Shoulder-of-Mutton Hill	(1893) p. 99. . .	Spine.
Acrodus sp. . . .	Dane Hills . .	(1889) p. 199 . .	—
" " . . .	Aylestone Road .	(1893) pp. 99, 100 .	—
" " . . .	—	† L.M. . . .	No. $\frac{1890}{315}$.
Gyrolepis quenstedti (Dames)	Aylestone Road .	(1893) pp. 99, 107	Scales attributed to this fish.
Colobodus frequens (Dames)	" " .	*Ibid.* . .	—
INCERTÆ SEDIS.			
'Fish-teeth' . . .	Leicester	† L.M. (1856)² . . p. 18	See 'MS. Donation Book,' 1855, p. 138; also p. 139, and 'Rep. Leic. Lit. and Phil. Soc.,' 1856, p. 18.
'Fish-spines' . .	"	† L.M. . . .	*Ibid.*
'Fish-scales' . .	Dane Hills	(1875) p. 45 . .	—
" . .	Aylestone	(1893) p. 99 . .	—
'Fish-coprolites' . .	Leicester	(1856)¹ p. 373 . .	—
AMPHIBIA.			
? LABYRINTHODONTIA.			
Footstep . . .	Leicester Shoulder-of-Mutton Hill railway cutting	(1856)¹ p. 370 . .	4 inches in diameter in form similar to the well-known Labyrinthodont footmarks of Storeton in Cheshire.
Footmark . . .	Leicester strata traversed by well-shafts	*Ibid.*, p. 369 .	-
AMPHIBIA.			
INCERTÆ SEDIS.			
Small pieces of bone .	Aylestone Road	(1893) pp. 99, 108	-
? REPTILIA.			
INCERTÆ SEDIS.			
Bones	Boring near Roman Wall Leicester (strata traversed by well-shafts)	(1856)¹ p. 369	—
Fragments of bone .	Shoulder-of-Mutton Hill railway cutting	*Ibid.*, p. 373	2 inches thick, largest 5 inches in length; 'another firmly cemented to an Ichthyodorulite.'
Fragment of tooth .	Bede House Meadows	† L.M. . .	No. $\frac{1890}{230}$.

Upper Keuper Grey and Red Marls, Leicestershire.

Genera and Species	Locality	Reference	Remarks
PLANTÆ.			
CONIFERÆ.			
Voltzia sp. . . .	Leicestershire	(1877) p. 73 .	'Casts of the spreading leaves.'

Upper Keuper 'Tea-green Marls,' Leicestershire.

Genera and Species	Locality	Reference	Remarks
ARTHROPODA.			
CRUSTACEA.			
Estheria minuta (Alberti)	Leicester . . .	(1856)[1] p. 373 . .	—
" .	Spinney Hills . .	† L.M. . . .	1907/2.2A &c.
INSECTA.			
Insect-wing . . .	" . .	(1876) p. 214 . .	Mr. Harrison, who discovered this, writes that it perished almost directly on exposure to the atmosphere.
PISCES.			
Colobodus frequens (Dames)	" . .	(1903) p. 120 . .	—
Teeth and scales of an Actinopterygian fish. (? Palæoniscoid)	" . .	† L.M. . . .	1893/1518
Fish-scales . . .	" . .	(1876) p. 214 . .	—
Teeth, scales, &c., of a Semionotoid fish	" . .	† L.M. . . .	1907/1.1A &c.

Upper Keuper Sandstone, Warwickshire.

Genera and Species	Locality	Reference	Remarks
AMPHIBIA.			
LABYRINTHODONTIA.			
Footprints of *Rhynchosaurus ? articeps* (Owen)	Rowington . .	† L.M. . . .	See 'Fourth Report of the Leicester Museum,' 1875-6, p. 15.

Lower Keuper Sandstone, Cheshire.

Genera and Species	Locality	Reference	Remarks
AMPHIBIA.			
LABYRINTHODONTIA.			
Footprints of *Rhynchosaurus* sp.	Runcorn . . .	† L.M. . . .	No. 1893/246.
Footstep of *Cheirotherium*	" . . .	† L.M. . . .	No. 1893/247.
" .	" . . .	† L.M. . . .	No. 1893/248.
" .	" . . .	† L.M. . . .	No. 1893/249.

Lower Keuper, Nottinghamshire.

Genera and Species	Locality	Reference	Remarks
PISCES.			
Semionotus sp. . .	Waterstones, Colwick Park	† L.M. . . .	Collected by Wilson.
AMPHIBIA.			
LABYRINTHODONTIA.			
Footprints of . .	Weston Cliff . .	(1860)[1] p. 62 . .	—

Lower Keuper, South Derbyshire.

Genera and Species	Locality	Reference	Remarks
PISCES.			
CRUSTACEA.			
Estheria minuta (Alberti)	Burton Bridge . .	(1863)[1] p. 100 . .	—
CHEIROTHERIUM.			
Footprints of . .	Ashby Road . .	(1869)[2] p. 160 . .	—
" . .	Brizlincote Hall .	(1869)[2] . . .	—
" . .	Burton Bridge . .	(1863)[2] pp. 2, 3 . .	—

A Bibliography of Works referring to the Flora and Fauna of the Trias (Keuper) in Leicestershire, and in some outlying localities.

1. (1850) Plant, John.—'Notice of the Discovery of Beds of Keuper Sandstone, containing Zoophytes in the vicinity of Leicester' ('Rep. Brit. Assoc.,' 1849, Trans. of Sect., p. 64). (*Gorgonia Keuperi*, Plant. This name must be regarded as a *nomen nudum*, the specimens so called being probably nothing more than worm-tracks or crustacean-tracks.)

2. (1856)[1] Plant, James.—'On the Upper Keuper Sandstone included in the New Red Marls, and its Fossils at Leicester' ('Quart. Journ. Geol. Soc.,' pp. 369–373), with sections, one containing errors. (Mentions occurrence of Algæ, *Equisetæ*, *Voltzia*, *Echinostachys oblongus*, Annelid tracks, Crustacea, *Estheria minuta*, teeth of Fishes, Ichthyodorulites, according to Sir P. de M. Egerton of the genus *Strophodus*, footmarks, various bones. This formed the basis of the flora and fauna down to 1893.)

3. (1856)[2] Anon.—'List of Donations to the Leicester Museum' ('Rep. Leicester Lit. and Phil. Soc.,' p. 18).

4. (1860)[1] Hull, Professor E.—'The Geology of the Leicestershire Coalfield and of the Country around Ashby-de-la-Zouch ('Mem. Geol. Surv.,' pp. 60–64). (Notice of *Estheria minuta* and of Labyrinthodont footsteps at Weston Cliff in South Notts.)

5. (1860)[2] Jones, Professor T. Rupert and W. Kitchen Parker.—'On some Fossil Foraminifera from Chellaston, near Derby' ('Quart. Journ. Geol. Soc.,' vol. 1860, pp. 452–7, pl. xix., xx.). (Some Foraminifera are here wrongly attributed to Triassic strata, and it has since been pointed out that they are more probably of Liassic age and glacially derived. See also *ibid.*, vol. xl. p. 771; and W. D. Crick and C. D. Sherborn, 'Journ. Northamp. Nat. Hist. Soc.,' vol. vii. p. 68; and T. R. Jones, 'Mon. Crag. Foram.,' pt. 11, p. 161, footnote, Palæont. Soc.)

6. (1862) Jones, Professor T. Rupert.—'A Monograph of the Fossil *Estheriæ* ('Palæont. Soc.,' pp. 58, 63, 65). (The occurrence of *Estheria minuta* in Leicestershire is noted, p. 58, and a recapitulation of Plant's list at p. 63, in a different form, with section, p. 66. *Estheria* recorded near Leicester.)

7. (1863)[1] Coleman, Rev. W. H.—'Geology of Leicestershire in White's History, Gazetteer of the Counties of Leicester and Rutland,' p. 100. (Mentions occurrence at Burton Bridge and Weston-on-Trent of tracks of *Labyrinthodon* in ripple-marked sandstones and *Estheria minuta* in waterstones or white beds, and alludes to Plant's discoveries.)

8. (1863)[2] Mosley, Sir Oswald, and E. Brown.—'The Natural History of Tutbury. ('*Cheirotherium* at Burton Bridge,' pp. 2, 3.)

9. (1866) Ansted, Professor D. T.—'The Physical Geography and Geology of the County of Leicester,' pp. 51–54. (Gives a general summary of organic remains, based on Plant's lists, and includes fossil Foraminifera from Chellaston.)

10. (1869)[1] Hull, Professor E.—'The Triassic and Permian Rocks of the Midland Counties of England' ('Mem. Geol. Surv.') (P. 5 alludes to fossils recorded by Plant in 'Q.J.G.S.,' xii. p. 371; also Foraminifera from Chellaston.)

11. (1869)[2] Molyneux, W.—'Burton-on-Trent: its History, its Waters, and its Breweries,' p. 165 (Footprints of *Cheirotherium*, Ashby Road).

12. (1874) Anon. (J. Plant).—'Report of the Leicester Lit. and Phil. Soc.,' p. 40. (*Tanystrophæus*, according to Professor Seeley, half a caudal vertebra, and not

referable to that genus; but in 'Q.J.G.S.', 1876, p. 218, he states that it should have been recorded as coming from the Rhætic.)

13. (1875) Plant, J.—'Report of the Leicester Lit. and Phil. Soc.,' p. 45. (Records from the Upper Keuper sandstone of Dane Hills and elsewhere, fish-remains [spines, teeth, and scales] *Estheria minuta*, worm-tracks, worm-holes, and 'cololitic' remains of marine worms.)

14. (1876) Harrison, W. J.—'On the Occurrence of the Rhætic Beds in Leicestershire,' 'Q.J.G.S.', pp. 212–218. (Fish-scales and an insect-wing recorded from the 'Tea-Green' marls, then classed with the Rhætics.)

15. (1877) Harrison, W. J.—'Sketch of the Geology of Leicestershire and Rutland, pp. 33–35. (A summary of previous records is given, and some fresh material is included.)

16. (1882) Harrison, W. J.—'Geology of the Counties of England and North and South Wales,' p. 155. (This contains a general summary of Triassic palæontology in the county.)

17. (1889) Browne, M.—'The Vertebrate Animals of Leicestershire and Rutland,' pp. 174, 199, 200. (Records *Acrodus keuperinus* and *Hybodus* sp.)

18. (1891) Browne, M.—'Notes upon *Colobodus*, a genus of Mesozoic Fishes, 'Brit. Assoc. Rep.,' 1891, pp. 664–5.

19. (1893) Browne, M.—'A Contribution to the History of the Geology of the Borough of Leicester,' 'Trans. Leicester Lit. and Phil. Soc.', pp. 123–240. (Gives a complete summary of all previous records within the area of the borough, and map and sections.)

20. (1900) Fox-Strangways, C., and Professor W. W. Watts.—'The Geology of the Country between Atherstone and Charnwood Forest,' 'Mem. Geol. Survey,' sheet 155, p. 33. (*Labyrinthodon*, Castle Donington.)

21. (1903) Fox-Strangways, C.—'The Geology of the Country near Leicester,' Appendix III., Palæontological Tables, sheet 156, pp. 104–123. (This complete analysis gives in the tables all the organic remains recorded from Leicestershire.)

22. (1904) Seward, Professor A. C.—'Catalogue of the Mesozoic Plants in the British Museum.' II. Liassic and Oolitic Floras of England, p. 8. (Refers to specimen named *Gorgonia keuperi*, but exhibited in the Fossil Plant Gallery, and compared, with others, to probably remains of *Voltzia*.)

23. (1905)[1] Fox-Strangways, C., and Professor W. W. Watts.—'The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch, and Loughborough,' 'Mem. Geol. Survey,' sheet 141, p. 31. (*Labyrinthodon* footsteps recorded from Weston Cliff, Donington Park.)

24. (1905)[2] Lomas, J.—'Report of the British Association' for 1904, p. 14 of reprint. Investigation of the Fauna and Flora of the Trias of the British Isles, Second Report of the Committee. (Record of Coniferous remains from Leicester in report by Dr. A. S. Woodward of Triassic fossils in the British Museum.)

Note on the Fossils from the Lower Keuper of Bromsgrove. By L. J. WILLS, *B.A., F.G.S., King's College, Cambridge.*

At the request of the Secretary of the Trias Committee I have put together the following notes on the fossils which I have found at Bromsgrove, in Worcestershire, as recorded in the 'Geological Magazine,' January 1907, p. 28. The horizon at which they occur is towards the top of the Lower Keuper of the older writers; that is to say, completely below the Keuper Marl. The majority are found in lenticular beds of marl and shale, while some appear in the sandstone. These lenticular patches are made of various types of rock, some being true marls, others sandy shales, green, brown, or red in colour. These last have so far proved barren. Some are very carbonaceous, and then appear to contain abundance of arachnid remains in a very fragmentary state. Just as the red marl, so the red sandstone is barren, the plants occurring in the grey, which they often stain red-brown. Most of the bones come from a marl conglomerate. Indications of similar plants have been traced at various

places all round the Droitwich basin at the same horizon. The fossils may be divided into those found in :—

(1) *The Sandstone.*

PLANTÆ.

Equisetites arenaceus (Jaeger): Pith-casts and leaves.
Zamites grandis (Arber): Leaves.
Voltzia, sp.: External surface of stem, male cone, and pith-casts of stems.
Coniferous wood.

PISCES.

Spine of *Acrodus.*
Coprolite.

AMPHIBIA.

Teeth and cranial bones of a Labyrinthodon (*Mastodonsaurus*)?

REPTILIA.

Hyperodapedon: Teeth, cranial and other bones.

(2) *The Shales.*

PLANTÆ.

Equisetites arenaceus (Jaeger): Pith-casts.
Equisetites sp.
? *Chiropteris digitata* (Brongn.).
? *Pterophyllum* sp. (Schimper and Mougeot): Leaves.
Voltzia sp.: Pith-casts of stem and male cones.
Conites sp.
? *Schizoneura* sp.

ARTHROPODA.

Estheria minuta.
Arachnid remains, probably of a scorpion.

PISCES.

Dipteronotus cyphus.
Scales.

The specimens are now in the Sedgwick Museum at Cambridge.

The Faunal Succession in the Carboniferous Limestone of the South-west of England.—Report of the Committee, consisting of Professor J. W. GREGORY (*Chairman*), Dr. A. VAUGHAN (*Secretary*), Dr. WHEELTON HIND, *and* Professor W. W. WATTS, *appointed to enable Dr. A. Vaughan to continue his Researches thereon.* (*Drawn up by the Secretary.*)

THE work has progressed steadily, but less rapidly than was anticipated owing to the necessity which has arisen of investigating the validity of certain genera and the correct application of specific names.

I.—*The Avonian Sequence in the Gower.*

The zoning of the Avonian sequence of the Gower Peninsula, undertaken in conjunction with Mr. E. E. L. Dixon in the summer of 1905, is now completed, and the results will be presented to the Geological Society early next session.

In this investigation the chief interest, from a zonal standpoint, centres in the occurrence of a higher faunal level than is known from any other point of the South-western Province. The level here referred to is that of the Oystermouth beds, of which the well-known Bishopston rotten-stones are the degraded representatives. The list of *genera* from these beds is practically identical with that from the Upper Tournaisian—a fact which may be taken to imply equivalence of environment. Important conclusions as to variation in time during the Viséan period have therefore been reached by comparing the several species of each genus at the Oystermouth level (uppermost Viséan) and those of the same genus in the Upper *Zaphrentis*-Zone (Upper Tournaisian). The

comparison of these two levels determines those characters of each gens which are indicative of old age; whereas the comparison of the brachiopods (or of the corals) at one and the same level determines those characters which are affected by convergence.

Mr. Dixon's careful study of the conditions of deposition which are implied by the several lithic types, increases very greatly the value of the zonal investigation by preventing the error of mistaking a change of fauna with change of conditions for a true zonal sequence dependent upon evolution.

II.—*The Carboniferous Sequence from Rush to Skerries, Co. Dublin.* (*In conjunction with* Dr. C. A. MATLEY.)

The stratigraphical relations have been admirably worked out by Dr. Matley, in spite of a quite remarkable intricacy of tectonic detail.

From a zonal point of view the main subject of inquiry is the true relative position of four distinct series whose sequence with one another is broken either by faults or gaps. The problem has been solved by a broad comparison of the coral faunas and their sequence in the several portions of the Irish section with the known coral sequence in the South-western Province. The relative position of the several portions has thus been established, and it has consequently become possible to draw up a detailed faunal sequence for the whole section. This sequence starts in the upper Tournaisian, and extends beyond the uppermost Avonian, being, however, notably incomplete in its middle portion.

The highest beds, which still exhibit an abundant Avonian fauna, (the Upper *Cyathaxonia* beds) include a maximum of *Posidonomya Becheri*, and at the same time contain several strikingly specialised forms of corals and brachiopods which also occur in the Lower Limestones of Scotland and in the uppermost Limestones of the western Midlands and Settle. Much light has thus been thrown upon the true correlation of the uppermost Avonian rocks in widely distant areas.

These results will be published at an early date.

III.—*Palæontological Work.*

The palæontological work arising out of these two papers has been very considerable, and is as yet incomplete.

Minute study of the material collected, and comparison with that already gathered from the South-western Province and other British localities, has shown the necessity of a reinvestigation of the value of the characters upon which certain genera have been founded—*e.g.*, the presence of a septum in Orthotetids, the existence of original fringes in Athyrids, the septation of Zaphrentids, &c.

I am also engaged upon the study of the types of Carboniferous Brachiopods preserved in the British Museum, and in this task Mr. S. S. Buckman has very kindly placed his long experience at my service.

I have also to acknowledge the great help which I have received from Mr. R. G. Carruthers in studying the Zaphrentids, and from many fellow-geologists who have sent me material for examination, and thus allowed me to keep in touch with the progress of research outside the areas in which I have myself worked.

So much remains to be done that I feel justified in asking for the continuance of this Committee for yet another year.

Investigation of the pre-Devonian Beds of the Mendips.—Report of the Committee, consisting of Mr. H. B. WOODWARD (*Chairman*), Professor S. H. REYNOLDS (*Secretary*), Professor C. LLOYD MORGAN, *and* Rev. H. H. WINWOOD. (*Drawn up by the Secretary.*)

THE principal objects which the Committee had in view were two in number :—

(1) To obtain a further series of fossils from the newly discovered Silurian beds of the area.

(2) To investigate the distribution in the field of a peculiar coarse ashy conglomerate, and to ascertain its relations to the other deposits of the neighbourhood.

With these ends in view a series of seven trenches was dug, and the information obtained from them was incorporated in a paper by the Secretary.[1]

The most easterly of these trenches was dug in a field about 300 yards S.S.W. of Tadhill Farm. It was carried to a depth of about 6 feet, and after passing through some 18 inches of surface-material, entered a deposit consisting mainly of very fine yellow and brown ash, with subordinate bands of coarse ash. Many of the bands were crowded with fossils, which were identified by Mr. F. R. C. Reed.[2] The series of fossils, though undoubtedly Silurian, and, in Mr. Reed's opinion, probably of Upper Llandovery age, was insufficient to determine the point with certainty.

A second trench dug at a point about 100 yards to the north of that in the fossiliferous tuff proved to be in trap (pyroxene andesite).

The remaining five trenches were all dug in the neighbourhood of the rifle butts on Beacon Hill (about a quarter of a mile to the north of Beacon Farm), where the coarse ashy conglomerate was originally exposed in a target pit. Four trenches dug at different points in the neighbourhood of the rifle-butts showed that the coarse ashy conglomerate here probably occupies the whole area between the northern and southern outcrops of the Old Red Sandstone. A fifth trench was opened on the slope of the hill to the north of the rifle-butts in hope of ascertaining the relation of the Old Red Sandstone to the igneous series, but after passing through 9 feet of Old Red Sandstone this trench was abandoned.

The thanks of the Committee are due to the Marquess of Bath and Sir Richard Paget, the owners of the land on which the excavations took place, to Mr. Ashman of the Beacon Farm and Mr. Huntly of Tadhill Farm (tenants), and to Mr. E. C. Treplin and Messrs. Wainwright and Hurd (agents).

The Committee ask to be reappointed, with a grant of 25*l*., for the purpose of investigating the pre-Devonian rocks of the Bristol district.

[1] Published in the *Quart. Journ. Geol. Soc.*, vol. lxiii. (1907), pp. 217–238.

[2] See list *op. cit.*, pp. 226 and 227.

Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Mr. J. E. MARR (*Chairman*), Dr. WHEELTON HIND (*Secretary*), Dr. F. A. BATHER, Mr. G. C. CRICK, Dr. A. H. FOORD, Mr. H. FOX, Professor E. J. GARWOOD, Dr. G. J. HINDE, Professor P. F. KENDALL, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, Mr. B. N. PEACH, Mr. A. STRAHAN, Dr. A. VAUGHAN, *and* Dr. H. WOODWARD.

THE part of the Report for 1906 which deals with the carboniferous zones in Flintshire was founded on work done by Dr. Hind and Mr. Stobbs. Their conclusions were presented in a paper read before the Geological Society of London on April 4, 1906. The Committee are not unanimously in agreement with some of the conclusions. On reference to the 'Abstr. Proc. Geol. Soc.,' No. 827 (1906), pp. 88–92, it will be seen that differences of opinion exist both as to the sequence and classification of the carboniferous rocks of Flintshire.

In 1895, at the meeting of the Association at Ipswich, a paper was read before Section C by Messrs. Garwood and Marr in which they suggested 'that a Committee be appointed to inquire into the possibility of dividing the carboniferous rocks into zones, to call the attention of local observers to the desirability of collecting fossils with this view, and, if possible, to retain the services of eminent specialists to whom these fossils may be submitted.' [1]

As the result of that paper the present Committee was appointed at the same meeting.

Much has since been done, largely owing to the work of the Committee, and especially by the researches of Dr. A. Vaughan, whose well-known paper on the 'Palæontological Sequence in the Carboniferous Limestone of the British Area' has in an eminently successful manner shown the possibility of the task for the consideration of which the Committee was initially appointed.

In these circumstances the Committee feel that the purpose for which they were appointed has been accomplished. Furthermore, another Committee has recently been appointed to enable Dr. Vaughan to continue his researches on the Faunal Succession in the Carboniferous Limestone of the British Isles with a grant. It seems undesirable to ask the Committee of Recommendations to make grants to two Committees for work of the same character. The Committee do not seek therefore reappointment.

The Committee in submitting this final report desire to place on record their appreciation of the energy and enthusiasm of their secretary, Dr. Wheelton Hind.

Report on the work done by means of the Grant and otherwise. Drawn up by the Secretary.

Mr. H. Bolton, in an admirable paper, brought before the Geological Society the work he had done on the fauna of a marine horizon at the base of the Bristol coalfield, a work towards which a portion of the grant was applied some two years ago. His paper will doubtless appear in the Society's Quarterly Journal, and it is unnecessary to say more here.

[1] *Report Brit. Assoc.*, 1895 [Ipswich], p. 696.

Mr. Tait, collector of the Geological Survey of Scotland, has been examining the Millstone grit succession east of Lancaster this summer, and Mr. Watson, of Owens College, has been working in the upper part of the Valley of the Nidd. It has not been possible to examine their collections in time for this report.

The Secretary was fortunate enough to secure a fine collection of plants obtained in an abortive attempt to find coal at Thirshfield, near Grassington, in the Valley of the Wharf. The exact place of the sinking is lat. 54° 3′, long. 2° 2′, and the shales are stated to be those which occur below a bed of Millstone grit.

Mr. Kidston has kindly examined the specimens for him, and the following list is the result :—

Sphenopteris elegans Bgt.	*Sphenophyllum tenerrimum* Ett. sp.
Calymmatotheca Stangeri Stur.	*Lepidodendron* sp.
Rhodia Moravica Ett. sp.	*Lepidostrobus* sp.
Sphenopteris sp.	*Small Lycopodiaceous* bract.
Calamites Ostraviensis Stur.	*Rhabdocarpus ?* sp.
Calamites sp.	

Mr. Kidston states, with regard to the horizon: 'I have not the slightest doubt that the bed these specimens come from is on the horizon of the Upper Limestone group of the Carboniferous Limestone series of Scotland.' At any rate we know that the Lower Limestone group of Scotland has a fauna which indicates the Upper *Dibunophyllum* zone.

Composition and Origin of the Crystalline Rocks of Anglesey.—Second Report of the Committee, consisting of Mr. A. HARKER (*Chairman*), Mr. E. GREENLY (*Secretary*), Mr. J. LOMAS, Dr. C. A. MATLEY, *and* Professor K. J. P. ORTON.

As stated in the Interim Report for last year, the problem first selected for a work has been that of the origin of the hornfels and other metamorphic rocks of the heart of the island. These rocks have been variously described as 'halleflinta,' pelite, and altered felsite. As their field-relation and microscopic characters will probably be discussed before long in another place, and as the analytical work is still incomplete, sufficient only will be said here to give an idea of the present nature of the rocks and the objects of the analysis. The numbers attached are those of the slides in the Secretary's cabinet, and the localities are referred to sheets of the Six-inch Ordnance maps.

The analyses given have been drawn up by Mr. John Owen Hughes, B.Sc., giving full details concerning the work, nearly all of which has been executed by himself. Unless otherwise stated the analysis is by Mr. Hughes.

No. 215A, 100A, 400A. These are all from the typical hornfels, and selected as varieties of it. They are fine-grained, dull, greenish rocks, with sometimes a slight schistosity, and are composed of quartz, with chlorite, fine mica, some iron-ore, and accessory minerals. They do not differ much in microscopic structure.

No. 100A contains dark spots, which are aggregates of chlorite full of inclusions of iron-ores and other minerals.

No. 400A was selected because it was collected from a point only a few yards from where a specimen, collected by Mr. Barrow when visiting the district with the Secretary in 1899, showed klastic structure. This rock is banded.

It is possible that in 215A and 100A the alkalies are too high, and we hope to revise those figures.

No. 215A.

7 *S.W.* '*Old Quarry*' *Ynys Fawr.*

	I.		II.
SiO_2	60·36		59·79
Al_2O_3	17·71		18·16
Fe_2O_3	6·68		6·23
FeO		1·88	
CaO		3·89	
MgO		2·27	
K_2O } Na_2O }	7·25		7·18
H_2O		0·17	
	100·21		99·57

No. 100A.

17 *S.W.* 530 *feet E.N.E. Llanfaelog Church.*

	I.		II.
SiO_2	58·99		58·76
Al_2O_3	18·85		18·63
Fe_2O_3	6·49		6·59
FeO	3·48		3·39
CaO		1·23	
MgO		2·07	
K_2O } Na_2O }	8·94		9·01
CO_2	0·43		0·42
H_2O		0·31	
	100·79		100·41

No. 400A.

17 *S.W.* *Coast, at Bone y Bedd.*

	I.		II.	
SiO_2	74·02		73·82	
Al_2O_3	12·13			
Fe_2O_3	0·89			
FeO	3·62			
CaO	1·10			
MgO	1·95			
K_2O	(*a*) 2·44	(*b*) 2·42	(*c*) 1·26	(*d*) 1·44
Na_2O	3·18	3·22	3·24	3·12
H_2O	1·54			

In above rock SiO_2 (determination II.) is by Miss C. Pearson, B.Sc., and alkalies (*c*) and (*d*) by Dr. Orton.

No. 112A is from the flaggy mica schists into which the hornfels passes on its south-east side—that is, the side away from the granite. The rocks into which these schists pass in their turn, still further away, have yet to be analysed.

No. 112A.

17 *S.W. Porth Nobla. S. Side.*

	I.	II.	III.	IV.
SiO_2	70·37	70·33		
Al_2O_3	15·37	14·95		
Fe_2O_3	0·34	0·71		
FeO	4·24	4·32	4·12	4·58
CaO	1·19	1·26		
MgO	1·93	1·84		
K_2O	2·20	2·34	2·01	
Na_2O	3·01	2·96	2·53	
H_2O (Hygroscopic)	0·16	0·13		
H_2O (combined)	1·03	1·08		
	99·84	99·92		

Nos. 18A and 214A are banded, highly crystalline rocks, which occur within the zone of hornfels, but are much coarser and more saccharoid, and this parallel structure a banding rather than a foliation. They may perhaps be called phenero-crystalline hornfels.

In 18A the dominant mineral is muscovite ; in 214A a pale hornblende. In 18A tourmaline is an abundant accessory.

No. 18A.

12 *S.E. South of Holyhead Road near B.M.* 96·5.

	I.	II.	III.
SiO_2	62·91	63·49	63·53
TiO_2	0·53		
Al_2O_3	16·52	25·97	25·57
Fe_2O_3	4·39	$Al_2O_3+Fe_2O_3$, including FeO	
FeO	4·47		
CaO	1·41	1·80	1·31
MgO	2·41	2·32	2·48
K_2O	2·57		
Na_2O	2·99		
CO_2	0·19		
H_2O (hygroscopic)	0·31		0·28
H_2O (combined)	1·83		1·78
	100·53		

Analyses II. and III. above, of SiO_2, $Al_2O_3+Fe_2O_3$, CaO and MgO, are by Miss C. Pearson, B Sc., and the second determination of H_2O (hygroscopic and combined) by Mr. R. W. Everett.

No. 214A.

13 *N.W. 600 feet N.W. 'M' of Maenygwyn.*

	I.	II.
SiO_2	60·38	60·33
Al_2O_3	17·10	16·51
Fe_2O_3	1·05	1·20
FeO	4·88	4·81
MnO	traces	
CaO	5·01	5·25
MgO	2·88	2·65
K_2O	3·59	3·80
Na_2O	3·67	3·85
H_2O (at 110°)	0·13	0·17
H_2O (above 110°)	0·95	1·03
	99·64	99·60

No. 151A is a Sillimanite Gneiss, from the heart of the central complex, and highly crystalline. Its peculiarity of composition will be at once obvious.

No. 151A.

12 N.E. Big boss N. Tyddyngyrfa. N.E. corner.

	I.	II.
SiO_2	54·01	53·99
Al_2O_3	21·19	21 05
Fe_2O_3	1·43	1·23
FeO	10·27	10·35
CaO	1·08	
MgO	1·74	
K_2O	3 94	4·18
Na_2O	1·83	1·66
CO_2	traces	
H_2O (at 110°)	0·602	
H_2O (above 110°)	2·71	2·79
S	0·24	
	99·04	

The percentage MgO in above analysis is probably too low.

The second determination of alkalies is by Dr. Orton.

Nos. 269A and 292–3A are two highly crystalline marbles from the mica schist zone, that of 112A. 269A is the beautiful Bodwrog Limestone. The other is a rock not before described. The insoluble residues consist of micas, calc. silicates, titaniferous minerals, and zircon, besides quartz.

No. 269A.

13 S.W. Bodwrog, E. of Church St. Twrog. 2nd Limestone from W.

	I.	II.
Residues insoluble in HCl	4·98	4·93
$Fe_2O_3 + Al_2O_3$	1·99	2·02
MnO	—	—
CaO	50·11	50·17
MgO	0·17	0·12
CO_2	42·57	42·01
	99·82	99·25
∴ percentage $CaCO_3$ =	89·48	89·59

Nos. 292 *and* 293A.

13 N.E. Ddraenog. S. of wood, about ½ mile to N.N.E.

	I.		II.
Residues insoluble in HCl	23·38		23·22
$Fe_2O_3 + Al_2O_3$	6·37		6·94
MnO	—		—
CaO	37·28		37·36
MgO	0·66		0·72
CO_2		30·42	
	98·11		98·66
∴ percentage $CaCO_3$ =	66·57		66·71

Slightly different specimens from adjacent parts of a slightly variable rock were mixed and analysed as one.

Besides these rocks from the hornfels and adjacent zones, certain others have been analysed for various reasons.

Of these No. 224A is one of the jaspers described in a paper by the Secretary.[1] It will be seen that this is wholly unlike any igneous rock, being essentially composed of silica, with a little impurity, chiefly iron oxide.

The analysis of a fine red phyllite associated with this rock is nearly completed.

No. 224A.

18 *N.W.* *In Limestone* 900 *feet S.W. of Hendrebach.*

	I.	II.
SiO_2	97·30	97·02
Al_2O_3	0·24	0·30
Fe_2O_3	1·74	1·78
	99·28	99·10

Alkalies were estimated but not separated :—

$K_2O + Na_2O$ between 0·56 and 0·46

No. 312A is one of the pink limestones associated with the jaspers. It is a true dolomite, but interesting from an unusual quantity of manganese, of which we hope to give a definite estimate next year. This, and not iron, is evidently the colouring matter, giving the peculiar delicate tint of rose. It occurs in the carbonates, which must therefore approach a little to Rhodocrosite.

No. 312A. *By* Mr. WM. ROBERTS, *B.Sc.*

Llanddwyn Island, Breakwater Cove.

	I.	II.
Residues insoluble in 20 per cent. HCl	5·80	5·87
$Fe_2O_3 + Al_2O_3$	2·70	2·75
CaO	29·89	29·97
MgO	18·63	18·89
CO_2	42·80	42·88
∴ percentage $CaCO_3$ =	53·37	53·51
„ $MgCO_3$ =	38·92	39·46

The proportion in true dolomite would be :—

$CaCO_3 : MgCO_3 = 54·35 : 45·65.$

No. 242A is a dark schist which gives a black streak. It occurs in the mica schist zone of the central district. Rutile is abundant. The presence of graphite has been determined qualitatively, and two estimates also made; but as Mr. Hughes wishes to revise these, the final result is held over until next year.

No. 270A, also from the mica schist zone, has been examined on account of the abundance of Rutile.

No. 270A.

13 *S.W.* *Bwlch y Fen.* 500 *feet S.W. MP. Holyhead* 14.

$SiO_2 = 42·94$
$TiO_2 = 2·54$

[1] *Quart. Journ. Geol. Soc.*, 1902, p. 425.

TiO_2 was determined by the gravimetric method, being precipitated as metatitanic acid, ignited and weighed as TiO_2.

No. 387A is a Mica Zoisite Diorite which occurs in the mica schists. Of this a silica percentage only was taken, and following upon it are several other rocks of which partial analyses or only silica percentage estimates were made.

No. 387A.

21 *N.W. Coast North of Aberffraw.* 600 *feet E. o Ynysoedd duon.*

	I.	II.
SiO_2	47·02	47·10

No. 377A is an epidotic schist occurring in the mica schists of the Holyhead region, and of importance as an horizon. It is evidently a basic rock.

No. 377A.

16 *N.E.* 300 *feet North of Cilbach, Borthwen Rhoscolyn.*

	I.	II.
SiO_2	42·23	42·30

Nos. 333A, 335A, 336A are from the late dykes of the island, some of which, at any rate—possibly all—belong to the latest of all its rocks except the pleistocene.

No. 333A is the prevalent type, an andesitic or sub-basic dolerite. The other two are much coarser, 336A containing some hornblende, and 335A being a true olivine dolerite. Many rocks of the group were described in papers by the Chairman, and their age discussed in a paper by the Secretary.

No. 333A.

Llanddwyn Island. Coast North of Ffynnon Sais.

SiO_2 = 50·92
Fe_2O_3 = 14·74
CaO = 8·51

The above analysis is by Miss E. Reyner.

No. 335A.

11 *N.W. Holyhead. Wall's End. Penlas Cove.*

SiO_2	42·34
$Fe_2O_3+Al_2O_3$	27·88
CaO	8 74
MgO	7·57

The above analysis is by Mr. Wm. Roberts, B.Sc.

No. 336A.

11 *N.W. Holyhead. Llaingoch.*

SiO_2	48·03
Fe_2O_3	7·31
Al_2O_3	11·59
CaO	8·51
MgO	3·39

The above analysis is by Mr. W. C. Evans.

A number of qualitative determinations have been made also. Most interesting among these are three of *barytes* from veins in Bodafon mountain and in the carboniferous limestone; one of *graphite* in a peculiar rock from Llanwenllwyfo; and one of *malachite* in a mica schist near Valley. *Copper pyrites* were also determined in a vein-stone in Ordovician shales near Rhosgoch.

Mr. Hughes contributes a report on the methods used, particularly on the precautions that have been taken to exclude error, and adds comments on a number of the analyses.

The Committee ask to be reappointed, and to retain the small balance left from the grant.

APPENDIX.

Methods of Rock Analysis. *By* JOHN OWEN HUGHES, *B.Sc.*

The weight of rock required for a complete analysis, adequately representing the average of the rock-mass, varies with the texture and homogeneity of the particular rock.

For the first four or five analyses samples weighing only about five or six grams were available; these, however, were very homogeneous in character, and the accuracy of the analyses would not suffer greatly from this cause. In the remaining rocks it was thought advisable to use larger quantities, thirty to fifty grams being the usual 'grind' prepared. In this way, after thorough mixing, it is possible to obtain a sample which better represents the whole rock-mass than if a smaller weight had been taken. Especially is this the case where there is banding or veining. In all cases the outside or weathered surface of the rock was rejected, the fresh cores being alone used.

Preparation of the Sample.—The time and the labour involved in the process of grinding the rock are great, and it is desirable that these should be reduced as much as possible. The following different methods have been employed:—

(1) The rock was ground up in a 'diamond' steel mortar in small quantities at a time, and the resultant mixture sifted through a ninety-mesh wire sieve. The part which did not pass through was once more crushed in the mortar, and again sifted, the process being repeated until all the rock had been in this way reduced to powder.

(2) The rock was broken into small pieces by means of a hardened steel hammer on a hardened steel plate. These were then crushed in the steel mortar and reduced to powder as in (1).

(3) [1] In this method the rock was broken up in a special steel revolving crusher (sold by Becker & Co.), and reduced directly to a state of fine powder, most of which passed directly through the ninety-mesh sieve. The part remaining when passed again through the crusher once or twice was pulverised completely, any hard particles being finally ground up by hand in an agate mortar.

This last method might be open to one objection—viz., contamination of the rock powder by metallic iron from the crusher; but this being of

[1] This method could only be employed for two rocks, as the crusher was not bought until March.

specially hardened material and the sample of rock so big, the chance of contamination is very slight, whereas the saving of time is enormous.

The powder thus obtained is sufficiently fine for the main fusion, but for the determination of ferrous oxide and alkalies the rock must be in a much finer state of division. For this purpose some of the main stock of powder was taken and ground by hand in an agate mortar until it was sufficiently fine to pass through a 120-mesh sieve.

Apparatus and Chemicals.—All fusions were carried out in platinum crucibles, platium dishes being also employed for all evaporations; a large silver basin was used in the estimation of alkalies. The glass beakers and flasks were all of a special make (R glass), very resistant to the action of solvents. The pipettes, burette and other measuring instruments were all standardised.

The reagents used were Merck's (specially pure); these were first carefully tested for impurities, and corrections applied for them where necessary. One sample of hydrofluoric acid contained an appreciable amount of iron, which had to be corrected for, and the calcium carbonate contained alkalies. The amount of alkalies present was determined in 20 grams of the carbonate, and the values obtained were used to apply corrections in the determination of alkalies in the rocks. Freshly distilled water was used throughout.

Methods.—Estimation of SiO_2, Al_2O_3, Fe_2O_3, MnO, CaO, MgO. For the determination of these about a gram of rock-powder was fused with about six times its weight of fusion mixture until decomposition was complete. From this fused mass the silica was separated and estimated. The metals were converted into chlorides and precipitated from solution in their proper order, iron and aluminium as hydroxides, the Fe_2O_3 estimated by standard permanganate after reduction with H_2S, and the Al_2O_3 determined by difference; manganese was precipitated as sulphide, calcium as oxalate, with subsequent conversion into oxide, magnesium as phosphate, the precipitates in all cases being dissolved and reprecipitated to ensure their purity.

Ferrous oxide was determined in about half a gram of the specially ground powder by solution in a mixture of sulphuric and hydrofluoric acids at a boiling temperature and immediate titration with standard permanganate solution.

Alkalies.—For the determination of alkalies the Lawrence Smith method was adopted.

The method was first tested by making a determination with a weighed quantity of pure potassium and sodium chlorides, and it was found to be quite reliable.

About half a gram of the specially ground powder was intimately mixed with ammonium chloride and calcium carbonate, and fused. The alkalies are thus converted into chlorides. The mass was thoroughly leached with water, and, after separating all traces of ammonium chloride and calcium carbonate, the mixed alkali chlorides were weighed. The potassium was separated as platinichloride and weighed, and the sodium determined by difference. A correction had to be applied for the alkalies present in the weighed quantity of calcium carbonate taken.

For the determination of CO_2 a weighed quantity of rock-powder was treated with hydrochloric acid, and the CO_2, after thorough drying and purifying, absorbed in a U tube containing soda lime, precautions being taken to keep the whole apparatus full of a current of air free from CO_2.

Hygroscopic water was determined by heating about a gram of powder in an air oven to a temperature of about 105° to 110° for an hour, and the loss in weight found.

The total water (hygroscopic and combined) was estimated by igniting about a gram of powder, contained in a porcelain boat, in a current of dry pure air, and absorbing the water in a weighed calcium chloride tube.

For the analysis of the limestones 269 A, 292, and 293 A, the method of procedure was as follows :—

About a gram of rock-powder was treated with excess of concentrated hydrochloric acid in a platinum dish at the temperature of the water-bath and evaporated to complete dryness. The residue was treated with dilute HCl and the insoluble part filtered off and weighed. The metals present in solution as chlorides were then estimated in the usual manner.

Investigation of the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.—Report of the Committee, consisting of Mr. G. W. LAMPLUGH (*Chairman*), Mr. J. W. STATHER (*Secretary*), Dr. TEMPEST ANDERSON, Professor J. W. CARR, Rev. W. LOWER CARTER, Dr. A. R. DWERRYHOUSE, Mr. F. W. HARMER, Mr. J. H. HOWARTH, Rev W. JOHNSON, Professor P. F. KENDALL, *and* Messrs. G. W. B. MACTURK, E. T. NEWTON, H. M. PLATNAUER, CLEMENT REID, *and* THOMAS SHEPPARD. (*Drawn up by the Secretary.*)

As was intimated in our report for 1905, the work during the past year has been directed to the investigation of the deposit at Bielsbeck, or Bealsbeck, in the Vale of York, which was examined between seventy and eighty years ago by the Rev. W. V. Harcourt, and yielded the remains of numerous extinct mammals. The object of our investigation was mainly to ascertain if any further evidence could be obtained to show the relation of this fossiliferous deposit to the glacial drifts.

The work, which was carried out under the superintendence of Professor P. F. Kendall, Messrs. G. W. B. Macturk and Thomas Sheppard, and the Secretary, confirmed the statements of the previous observers: (1) that the deposits yielding the bones rested immediately on the Keuper Marl ; (2) that they have been accumulated in a boggy hollow on an old land surface ; and (3) that at this particular locality there is no material that can be assigned to the direct agency of ice. It therefore still remains a debatable question whether the bone-bearing material was accumulated before, during, or since the Glacial period ; and it would appear that the elucidation of this matter will depend upon the investigation of a wide area to determine what was the condition of the Vale of York during that period.

The absence of glacial deposits in this part of the country may, on the one hand, imply that the area was never glaciated ; or, on the other hand, it may mean that glacial deposits once existing have been entirely removed. If the former be the case, the bone-bearing deposits might belong to the pre-Glacial or to any younger stage ; while if the latter

supposition should find confirmation, the deposit must be later than the glaciation.

The site of the original excavation is still visible, the hollow from which the 'marl' was dug being now a reedy pond. The new sections consisted of four pits sunk in the vicinity of the pond.

These pits were roughly from two to four yards square, and were carried down until the Keuper Marl was reached or the work was stopped by the influx of water. They were supplemented by several bore-holes put down to determine the extent of the deposit.

The sections revealed in the pits were as follows :—

Section 1.

	Feet	Inches
Surface soil	0	9
Sand, with small pieces of angular chalk and flint	2	0
Gravel of rounded chalk and sub-angular flint	1	6
Silty blue-black marl or loam, the upper surface very irregular and penetrated by 'pipes' and pockets of gravel from the bed above	3	9
Marl as above, with specks of vivianite	1	0
Black marl	6	0
Lighter-coloured marl, passing downwards into gravel (chiefly flints)	7	6
Total depth reached	22	6

Section 2.

	Feet	Inches
Surface soil	0	9
Sand	1	9
Gravel	2	0
Dark silty marl, with gravel	2	6
Dark marl	4	0
Lighter marl	4	0
	15	0

Section 3.

	Feet	Inches
Soil	1	0
Sand	2	0
Gravel	3	0
Grey marl, passing downwards into black	7	6
Coarse gravel	0	6
Solid Keuper Marl, blue	3	0
Solid Keuper Marl, red	1	0
	18	0

Section 4.

	Feet	Inches
Soil	0	9
Sand	3	6
Gravel	1	6
Keuper Marl, its surface dipping at 1 in 3 towards the old marl pit	1	3
	7	0

From the black muds or marls which occurred below the superficial gravels in these pits the following fossils were obtained :—

Bones.—For the following determination we are indebted to Dr. C. W. Andrews, F.R.S., of the British Museum (Natural History), South Kensington.

MAMMALIAN REMAINS.

Cervus sp
Bos sp. (two vertebræ).
Bos sp. (smaller than *longifrons* or *primigenius*).
Bos primigenius.
Elephas (rib and left scapula).

The bones were not confined to any particular layer, but were distributed sporadically throughout the mass of the marl. The overlying gravels, however, contained neither bones nor other vestige of contemporaneous life, possibly because of their removal by percolating water.

Shells.—The molluscan remains distributed through the marl belong to existing land and fresh-water species, many of which are still living in the neighbourhood. They are all species of wide range, and afford no definite indications as to climate. These species, kindly determined for the Committee by Mr. J. W. Taylor, of Leeds, are as follows :—

MOLLUSCA.

Limnæa peregra.
,, *palustris.*
,, *truncatula.*
Succinea putris.
,, *elegans.*
Hyalinia nitidula.
Zonites fulvus.
Helix nemoralis.
,, *hispida*, var. *concinna.*
,, *pygmæa.*
,, *pulchella.*
Vertigo antivertigo.
,, *pygmæa.*
Cochlicopa lubrica.
Carychium minimum.
Pisidium amnicum.
,, *pusillum.*
,, *nitidum.*
,, *milium.*
,, *obtusale.*
Bythinia tentaculata
Valvata cristata.
Planorbis spirorbis.
,, *contortus.*
,, *glaber.*
,, *marginatus.*

Plants.—The material also contained plant remains, but was difficult to wash and sift. Some small seeds were, however, picked out by Mr. Stainforth, and were submitted to Mr. Clement Reid, F.R.S., for determination, who recognised the following :—

SEEDS OF PLANTS.

Ranunculus sceleratus.
,, *repens.*
Viola sp.
Œnanthe aquatica Poir.
Rumex.
Sparganium erectum ?
Carex.
Alisma plantago.

With regard to the above list Mr. Reid remarks: 'If these were all that were found at Bielsbeck, they are an exceptionally poor set, which shows nothing as to climatic conditions.' 'There are only one or two seeds of meadow plants among them, and no dry soil plants.'

Insects.—Besides the above, the deposit contains the remains of beetles, but much of the material has not yet been specifically determined. The following may be mentioned :—

COLEOPTERA.

Donacia (sp. ?) (an almost complete specimen).
Hister (sp. ?) (elytron).

Further Notes on the Deposits.—The Bielsbeck bone-bearing deposits apparently occupy a depression or hollow in the Keuper Marl of

undetermined width, and it appears as though this hollow is isolated and inclosed by the marl, though it is just possible that it may represent a portion of a filled-in valley or trench, the direction of which has not been traced.

Scattered through the marl at various depths were angular or slightly rounded black flints in large numbers, and these in some cases formed a definite layer. Along with the flints were occasional pebbles of quartz and of sandstone (probably Carboniferous). None of these pebbles showed striæ or other indication of glacial action.

The overlying gravel was mainly composed of flint and chalk from the neighbouring Wolds, along with scattered fragments of quartz, sandstone, &c. (like those found in the underlying marl), and *Gryphæa* and other fossils from the Lias. This gravel is the feather-edge of a wide fan which can be traced up to the mouth of a valley that drains from the Wolds at Market Weighton. In the thicker parts of this gravel, towards the mouth of the valley, other pebbles besides the above have been detected, including the well-known porphyrite which is characteristic of the upper part of the East Yorkshire drifts. The wide extent and depth of this gravel suggests that it has been spread out by floods from the melting ice, when the ice-margin abutted upon the eastern slopes of the Wolds. The present valley appears to be too short to supply a stream powerful enough to spread a sheet of gravel of these dimensions.

The thanks of the Committee are due to W. H. Fox, Esq., for permission to excavate; to the tenant, Mr. Howes; to Mr. W. H. Crofts; and to the contractor, Mr. Thomas Moate.

The Committee had contemplated work on another site in East Yorkshire, but have found difficulty in obtaining the requisite permission. Pending a final settlement of this matter, they ask for reappointment, with power to use the unexpended balance of their grant.

South African Strata.—Interim Report of the Committee, consisting of Professor J. W. GREGORY (*Chairman*), Professor A. YOUNG (*Secretary*), Mr. W. ANDERSON, Professor R. BROOM, Dr. G. S. CORSTORPHINE, Mr. WALCOT GIBSON, Dr. F. H. HATCH, Mr. T. H. HOLLAND, Mr. H. KYNASTON, Dr. MOLENGRAAFF, Mr. A. J. C. MOLYNEUX, Mr. A. W. ROGERS, Mr. E. H. L. SCHWARZ, *and* Professor R. B. YOUNG, *appointed to investigate and report on the Correlation and Age of South African Strata, and on the question of a Uniform Stratigraphical Nomenclature.*

THE Committee have continued the discussion of the subject by correspondence; but as the members of the Committee are scattered through South Africa, India, and Europe, the work has been slow. It will therefore be impossible to issue a report in time for the Leicester meeting, as had been hoped.

Preliminary reports have been drawn up by the members of the Committee, representing Cape Colony, the Transvaal, and Rhodesia. These reports have been submitted to all the members of the Committee, who have been asked to vote by post on the chief points at issue. It is hoped that a report will be prepared in time for the 1908 meeting of the Association.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Dr. J. E. MARR (*Chairman*), Professor P. F. KENDALL (*Secretary*), Dr. T. G. BONNEY, Professor W. J. SOLLAS, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Dr. J. HORNE, *and* Messrs. F. M. BURTON, J. LOMAS, A. R. DWERRYHOUSE, J. W. STATHER, W. T. TUCKER, *and* F. W. HARMER, *appointed to investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.* (*Drawn up by the Secretary.*)

THE present report records a comparatively small series of erratics, and to this three causes have conspired; the Committee consider that unless some new and significant facts of distribution are disclosed no useful results would accrue from the multiplication of records of well-known rocks from localities contiguous to those in which similar rocks have already been noted. The early date of the Leicester meeting has thrown the preparation of the report upon a time when the Secretary's leisure-time is limited, and when many of the active workers are afield; finally, a very large series of specimens are in the hands of the section-cutters. It is hoped that when they have been submitted to microscopic examination a valuable series of identifications will be obtained, especially among the basalts and dolerites of the east of England. Dr. Flett has kindly promised to give the Committee his invaluable assistance in this work.

The boulders recorded in the present report call for brief comment.

The Shap granite and Borrowdale volcanic rocks recorded from Geltsdale are extensions of the known range of these rocks across the outer ridge of the Cross Fell escarpment, though not beyond the drainage basin of the Solway.

The series of records furnished by Messrs. Culpin and Grace are of very great value and importance, as they tend not only to connect the isolated groups of erratics in the country between Doncaster and Barnsley, but also to extend the area of boulder-strewn country in a north-easterly and south-westerly direction. Some light may possibly be thrown upon the remarkable group at Crosspool, near Sheffield.

Mr. Hawksworth's discovery of Silurian grit in a high-level gravel at Rothwell Haigh establishes the superior limit of age of that interesting deposit.

The identification by Mr. J. H. Howarth of an example of a dolerite of the same type as that of Fans encourages the hope that other competent petrologists with experience of the basic rocks in other areas may clear up the uncertanity that has enshrouded the origin of the basalt boulders of Eastern England.

Mr. Maule Cole's observations may ultimately prove to be outside the purview of a Committee dealing with erratic blocks, as it has been suggested that the quartz pebbles which strew the higher Wolds of Lincolnshire and Yorkshire are merely the relics, practically *in situ*, of Tertiary gravels that once overspread the area. In the meantime, however, while the question is *sub judice*, an impartial record must be kept.

The occurrence of finely preserved ammonites from the Upper Lias under the Wold escarpment near South Cave derives its significance from

the fact that there is no known outcrop in the neighbourhood which could have yielded the specimens.

Notes are promised for next year's report showing that, just as has proved to be the case with the Upper Cretaceous belemnites, some of the Liassic ammonites of the Drift of Holderness appear to be aliens in Yorkshire.

The Committee welcome the promise of renewed activity on the part of the Belfast Naturalists' Field Club, that has done much good work in the past.

A considerable change of the *personnel* of the Committee is necessitated by the retirement of Dr. Marr from the position of Chairman, which he has held since the year 1899, and of Professor P. F. Kendall from the Secretariate, to which he succeeded upon the retirement of the late Dr. Crosskey.

The Committee ask for reappointment, with Dr. A. R. Dwerryhouse as Secretary, and Professor Kendall as Chairman.

Cumberland.

Geltsdale.—

Reported by Professor P. F. Kendall.

In the cone of dejection of the cloud-burst of 1894 in New Water, just below Henshaw Wood, Shap granite, Borrowdale lavas and ashes.

Yorkshire.

Communicated by the Yorkshire Boulder Committee (Secretary, J. H. Howarth, *F.G.S.).*

Reported by H. Culpin *and* G. Grace.

Bentley, near Doncaster.—In the sinking of the Bentley pit, two miles north of Doncaster, boulder clay has been passed through at a depth of 55 to 75 feet below O.D. The boulders are principally Permian sandstone. There are grits, gannisters, and Carboniferous limestones. Coal Measure shale with *Anthracomya Phillipsi* also occurs.

Tickhill, near Doncaster.—In a distance of two miles the South Yorkshire Joint Railway has opened out four cuttings through boulder clay. The most southerly cutting is at All Hallows Hill, near Tickhill, and a little over six miles south of Doncaster. In its deepest part the clay exceeds 20 feet in thickness, the base not being exposed. The boulders are Permian limestone up to 12 cubic feet. There are grits, gannisters, and Carboniferous limestones, the latter ranging up to 2-foot cubes. Some of the Carboniferous limestone blocks contain *Productus cora*, *P. scabriculo-costatus*, *P. longispinus*, and *Pterinopecten*. There are a few Lake District boulders. The stones are sub-angular and are well scratched. Boulders reported are as follows: All Hallows Hill, near Tickhill—Lake District volcanic ash, 1-foot cube.

Kirk Sandal.—From trench on South Yorkshire Junction Railway, $1\frac{1}{4}$ mile south of Kirk Sandal Church—Lake District volcanic ash $18 \times 13 \times 13$ inches.

This is 3 miles N.E of the well-known patch of boulder clay at Balby.

Alverley.—¼ mile N.W. of Alverley—Barrowdale andesite 6 × 4 × 4 inches. This is one mile S.W. by W. of Balby.

Stapleton Park.—2½ miles S. of Knottingley—Lake District volcanic ash 18 × 10 × 6 inches.

Lound, near Retford.—1½ mile E. of the village of Lound—Magnesian limestone, grits, and a small fragment of volcanic rock, probably Lake District volcanic.

Reported by E. HAWKSWORTH, *Rothwell Haigh, near Leeds.*

Silurian grit, hæmatite.

Reported by L. GLAUERT, jun., *Sheffield.*

Hornsea.—In a series of rocks sent to me (J. H. H.) by Mr. Glauert, and collected on the shore at Hornsea, are two exactly similar to the olivine dolerite of Fans, Berwickshire.

Reported by Professor P. F. KENDALL.

Pateley Bridge.—At head of Colthouse Gill, 850 feet O.D., fragments of the 'shell bed.' These erratics are further up the valley and at a much higher altitude than any known outcrop of the shell bed on the south side of the Nidd Valley.

Transmitted by the East Riding Boulder Committee (J. W. STATHER, *Secretary*).

Reported by the Rev. E. MAULE COLE.

Wetwang.—In the driftless area round the vicarage the scanty soil covering the chalk contains large numbers of quartz pebbles.

Reported by G. W. MACTURK.

South Cave.—At 200 feet O.D., near the railway station, a fine specimen of *Ammonites fibulatus* in a bed of rounded chalk gravel. On the Beverley Road, at 125 feet O.D., a specimen of *Dactylioceras* (*Ammonites*) *commune.*

The occurrence of these two very fine specimens of ammonites from the Upper Lias is a striking fact, as the Lias outcrop lies about a mile and a half to the west, and the Upper Lias is very feebly represented, if at all.

ISLE OF MAN.

Reported by T. AXON, *of Stockport.*

Glen May.—A boulder of grey granite about 9 feet in length.

[The rock is characterised by the occurrence of biotite and light grey idiomorphic crystals of felspar with zoned structure. It much resembles a granite collected by Mr. Axon and the writer near the eastern end of the clints of Dromore, Kirkcudbrightshire.—P. F. K.]

The Iron Ore Supply of the Scandinavian Peninsula. *By* HJ. SJÖGREN.

[Ordered by the General Committee to be printed *in extenso*.]

THE iron ore deposits of the Scandinavian countries are not uniformly distributed all over the peninsula, but confined to certain ore-bearing areas, or 'ore provinces.' As an 'ore province' I designate an area characterised by a certain geological structure genetically connected with the ore-bearing rocks of the area.

An 'ore province' may geologically be built up by igneous rocks, or by sedimentary deposits, or by crystalline schists, or by two or three of these kinds of rocks together. The Scandinavian Peninsula furnishes us with examples of ore provinces of very different geological types. Considering only the Scandinavian ore provinces carrying iron ores, we may distinguish six such provinces.

The geologically best known is the 'ore province of Central Sweden,' the 'Järnbäraland' (iron-bearing land) of the ancient history of Sweden. It is characterised by a rather complicated geological structure, composed of crystalline schists and of acid and basic igneous rocks, all belonging to the Archæan age.

The same geological features are exhibited in the 'ore province of the south coast of Norway,' which may be considered as a westerly extension of the ore province of Central Sweden. Also the comparatively confined 'ore province of Syd-Varanger,' in the most north-easterly part of Norway, shows the same geological conditions.

The 'ore province of Norrbotten' is also composed of rocks of Archæan age, but the chemical and petrographical composition of the rocks is partly different, syenite and syenitic porphyries playing a prominent part in the composition of the ore-bearing ground.

The 'ore province of Northern Norway,' comprising the coast belt between the latitudes of 65° 50′ and 69° 10′ and the valleys penetrating into the country from the sea, is composed of metamorphosed schists of Cambro-Silurian age. The ore deposits are associated with beds of limestone. Through the erosion proceeding from the Atlantic, the ore-bearing horizons have in a number of places been laid bare. The igneous rocks occurring within this area seem not in any way to be connected with the ore deposits.

Lastly we have to mention the 'ore province of Christiania,' with a great number of mostly small ore deposits connected with the eruptive post-Silurian rocks of the Christiania basin.

Considering the importance of the different ore provinces in respect to the quantities of ore obtainable in each of them, the ore province of Norrbotten takes the first place, containing several great deposits, of which one (Kiirunnavaara) must be counted among the greatest in the world. Next comes the ore province of Northern Norway, with immense quantities of lean iron ores. The ore province of Central Sweden during many centuries played a rôle as the chief producer of Swedish iron, and the same may be said of the ore province of the south coast of Norway in respect to Norway. The ore province of Syd-Varanger will in the near future become a very important ore-producer. The ore province

of Christiania is, on the contrary, in respect to iron ores without any practical importance.

These ore provinces contain more than 90 per cent. of all the iron ore supply available in Scandinavia, and probably about 99 per cent. of all the iron ore hitherto mined in Sweden and Norway have been extracted from the mines of these ore provinces.

From a geological point of view the iron ores of the Scandinavian Peninsula may be classified as follows :—

1. *The Ores of the Archæan Crystalline Schists.*—These ores belong to the part of the Archæan rocks which are crystallised in the anamorphic zone and interwoven with intrusive granite. The ores occur associated with ortho- and para-gneisses, granulites, and dolomitised or silicified limestones.

The ores of this class were long considered as sedimentary deposits laid down together with the over- and under-lying crystalline schists. In several papers from the beginning of the nineties, and later, I have pointed out that these ores must have been formed in the vertical or inclined positions they now show, and after the plication of the schists had taken place. I also tried to show that metasomatic processes have played a prominent part in the formation of these ores. I consider it most probable that the ores were formed in the deep-seated zone from thermal iron-bearing solutions, acting under high pressure. To what degree these solutions were magmatic, carrying ore substance from below, or if the small amount of water contained in the rock was the chief agent in collecting and concentrating the iron, is uncertain. At all events, the process was different from the action performed through solutions circulating in open channels.

The ores of this class chiefly occur in the ore province of Central Sweden, but they are also represented by several great deposits in the ore provinces of the south coast of Norway, of Norrbotten, and of Syd-Varanger.

2. *The Ores of the Porphyries* (*also classified as Keratophyres*) belong to a division of the Archæan system younger than the old granites, but still plicated in pre-Cambrian time.

The genetic connection of the ores in question with the porphyry rock is so manifest that it has been admitted by all who have expressed an opinion on the subject. But the nature of this connection is interpreted in very different ways. The ores have frequently been compared with the great iron ores of the Eastern Ural, Wissokaja Gora, Gora Blagodat, &c., also connected with syenitic rocks, and have, like these, been considered as products of magmatic differentiation. But it seems not unlikely that these ores are also produced in a manner not differing essentially from the formation of those of the first class, that is, through the agency of iron-bearing aqueo-igneous solutions. The ore deposits belonging to this group are confined exclusively to the ore province of Norrbotten : some of them are among the largest in the world.

3. *The Ores of the Basic Eruptive Rocks* occur as differentiations in intrusive bodies of diabase and gabbro, forming stocks, bosses, and laccolites within schists of Archæan and Silurian age. The ores of this kind form a natural and well-defined class met with in all parts of the world. That these ores are genetically connected with eruptive rocks has long been admitted. Their nature of differentiation facies is evident from their structural characters, which are the same as those of the eruptive

rocks, as well as from the fact that they frequently present all degrees of transition into the normal rock.

The ore deposits belonging to this class are not confined to any of the ore provinces mentioned above, but occur scattered all over the peninsula, both in Sweden and Norway.

4. *Ores associated with the Metamorphosed Schists of Cambro-Silurian Age* chiefly occur in the mica-schists group characterised by mighty beds of limestone.

The deposits of this class are geologically characterised by belonging to a ferriferous formation of vast horizontal extent, occupying nearly the same geological horizon, and they occur as regular members of this sedimentary series. If the ores are to be considered as primary sedimentary deposits, or if they constitute secondary concentrations of leaner iron-bearing formations, is still an open question, not only of theoretical but also of great practical importance.

On the whole, one may consider these deposits as the roots or the deepest comparatively unconcentrated parts of regionally metamorphosed chemical deposits laid open by the deeply penetrating firths and valleys of the Norwegian coast, the upper probably more concentrated and thus richer parts of the same deposits having been destroyed by erosion.

These ores, which form a geologically very well-defined class, are also territorially confined to a certain ore province, that of Northern Norway.

5. *Contact Formations connected with Acid Eruptive Rocks of post-Silurian Age* occur in the Archæan gneisses and in the Silurian limestones and argillaceous schists of the Christiania Silurian basin.

The igneous rocks of the Christiania region comprise, according to Brögger, several different types, of which the more basic, *i.e.*, gabbro-diabases, basic pyroxene-mica, and nepheline-syenites and quartz-bearing pyroxene-syenite, are the older, and the acid types, *i.e.*, red quartz-syenite (Nordmarkite), soda granite (Grorudite) and granitite are the younger.

The intrusives are bordered partly by Archæan rocks, partly also by the Silurian strata, and by porphyry outflows. The contact deposits are found in all these different pregranitic rocks. Most of the deposits are connected with the red quartz syenite (Nordmarkite), some of them with the soda granite (Grorudite) and with the granitite.

These ore deposits are, though many in numbers, yet quantitatively too insignificant to play any commercial rôle. In earlier times several hundreds of them were worked.

6. *Lake and Bog Ores belonging to the most recent Geological Period.*—These ores occur scattered over most provinces of Sweden and the southern part of Norway; yet they occur amply only in such regions of the country where the ground consists of moraines and gravel, and they are found more sparingly in the parts of the country which are covered by glacial and post-glacial marine deposits. In short, the lake and bog ores are most frequent above the marine level of the Glacial period. A certain connection with the distribution of the peat-mosses is indicated.

The different geological ore groups defined above are characterised by mineralogical and chemical properties, which have determined their technical utilisation.

The lake and bog ores of Group 6 formed, on account of their cheap exploitation and easy reduction, the raw material of the oldest iron manufacture in the Scandinavian countries, and were used long before the blast-furnace process was known. Carl von Linneus for this reason called

them *Tophus Tubalcaini*, after Tubal Cain, the first blacksmith. But their importance has been decreasing as the iron manufacture has become a great industry.

The ores of *Group* 1 (Archæan, crystalline schists) were next utilised. Owing to the absence of phosphorus, which characterised a part of these ores, and to other excellent qualities, they were for centuries the only ores that were mined in Sweden, and they have been the raw material of the Swedish iron that has won world-wide renown. The supply of the ores of this kind, free from phosphorus, is already to a great extent consumed, and that which is left is very limited.

The ores belonging to *Group* 2 (ores connected with porphyries) could not for a long time be utilised on account of their high percentage of phosphorus. Besides that, the situation of the deposits in the extreme north of the Scandinavian Peninsula deterred from mining enterprises.

Some of the deposits belonging to this group are among the greatest in the world. Thanks to the basic refining methods, they have now gained great importance having however as yet chiefly given rise to ore export on a large scale. These ores, rich in phosphorus, are also more and more utilised for the Swedish iron industry.

Group 3.—These ores are chemically characterised by a high amount of titanium, making them very difficult to reduce. They have hitherto been made use of only on a very small scale, and it does not seem likely that this state of things will change as long as there is an ample supply of better ores. Vast deposits of these ores occur in Sweden as well as in Norway.

Group 4 (ores in the metamorphosed Cambro-Silurian).—The ores included in this group occur only in the metamorphosed Silurian formation of Norway. They are characterised by a low percentage of iron, and have not as yet been utilised for the Scandinavian iron industry, but preparations are going on for mining and exporting them to England and Germany on a large scale, after subjecting them to magnetic concentration.

The ores belonging to *Group* 5 have a limited distribution within the Silurian and Archæan rocks of the Christiania field. They may be considered as of no practical importance.

Ore Supply.—The Scandinavian countries, especially Sweden, have been from ancient times regarded as very rich in iron ores. Swedenborg gives expression to this opinion when saying, 'Mars per omnes Sueciæ provincias sparsus est.' This view has arisen from the fact that a famous iron manufacture was carried on in Sweden during centuries without the known ore supplies showing any sign of failing, or even of being strongly exploited. The conclusion that the ore supplies should last for an unlimited future is, however, not well founded. In former times, up to 1870, the output of iron ore required for the home manufacture was so insignificant that one must sum up all the output of the mines during perhaps four or five centuries to get a quantity that will balance the production during a few decades of later time. And since from the beginning of the last decade of the nineteenth century a great exportation of iron ore commenced, which increased with every year, it is probable that the output of iron ore in Sweden during a few years at present is equivalent to the whole output of the Swedish mines during four hundred to five hundred years before 1870.

Several attempts to make quantitative estimations of the iron ore

supply of Sweden have already been made. Professor G. Nordenström, the late Director of the Mining School in Stockholm, introduced for this purpose the conception of *ore area*, or ore section, *i.e.*, the horizontal section of the ore deposits expressed in square metres or square feet. Since most Archæan ore deposits have a nearly vertical position, the horizontal section (=ore area) gives a comparative expression for the magnitude of the deposits. In 1893 he published a statement of the ore areas of the principal iron deposits of Sweden; in a completed and revised state he published it a second time in the year 1898, on the occasion of the meeting of the Iron and Steel Institute in Stockholm.

The statement of Professor Nordenström shows in abridged form the following figures for the principal mining fields :—

	Ore Area in Square Metres
Norrbotten—	
Kiirunavaara-Luossavaara	430,000
Gellivare	200,000
Svappavaara	38,000
Central Sweden—	
Grängesberg	90,000
Other mines in Central Sweden	156,000
Titanic Ores—	
Routivaara	300,000
Taberg	260,000
	1,474,000 m^2

The experience of later years has shown that the figures given by Professor Nordenström are in some cases much exaggerated.

In order to convert the figures of ore area into tons of ore won by sinking the average level of the mine one metre, one has to take into consideration the weight of the ore and the percentage of ore in the rock mined, and by introducing also a measure for the depth, determined either by drilling or by magnetic survey, or simply by an estimation based on the experience from other mining enterprises in the same district, one may arrive at a figure for the probable ore supply of a mine, or of the whole district.

In this way one gets an expression for the presumable ore quantity, or the 'ore expectant,' as the American mining engineers express it.[1]

Of course every such estimation leaves ample room for subjective discretion, and can at best only be considered as a rough approximation to the truth. The first estimation of this kind, comprising the whole country, was made in 1898, and is found in 'Vermländska Bergsmannafören. Annaler' for this year. The iron-ore supply of Central Sweden is estimated to be 110 M.T.,[2] and in Norrbotten at 520 M.T. Already in the previous year Mr. Hj. Lundbohm made an official survey of two of the greater ore deposits of Norrbotten, viz., Kiirunnavaara and Luossavaara, and calculated the ore quantities obtainable above the level of Lake Luossajärvi to be in Kiirunnavaara 215 M.T., and in Luossavaara 18 M.T.

[1] Ore expectant is 'the prospective value of a mine beyond or below the last visible ore, based on the fullest possible data from the mine, and from the characteristics of the mining district.'—Philip Argall, *The Engineering and Mining Journal* of February 14, 1903.

The 'ore expectant' deals rather with the future than with the present, and with the probable life of the property as a producing mine.

[2] Here and in the sequel M.T. means millions of metre-tons.

In the year 1905, in connection with a motion made in the Swedish Parliament for laying an export duty on iron ore, the question of ore supplies was again discussed. A. E. Törnebohm, at this time Director of the Geological Survey of Sweden, made an official statement, in which he expressed very optimistic views. In respect to Central Sweden he came to about the same figures as those already mentioned above, viz., 105 M.T.; but in the estimation of the ore quantities of Norrbotten he made the arbitrary assumption that the ore bodies should reach to depths of 300 metres, or even of 500 metres, with the same area as at the surface. In this way he came to a figure for Kiirunnavaara and Luossavaara of 793 M.T., Gellivara 128·5 M.T., and for the other mines in Norrbotten to 175 M.T.; total for Norrbotten 1096·5 M.T.

Criticising this estimation I pointed out that no results of experience at all were accessible concerning the depth of the ore deposits of Norrbotten, that their geological conditions and mode of formation were unknown, and that the experience from other districts in Sweden showed that the ore area of each single ore body tends to decrease with the depth.

For this reason I believed that the statement could not be verified with such uncertain depths. Accepting the calculation of Mr. Lundbohm from the year 1898 of 205 M.T. above the level of Luossajärvi, I added 100 M.T. as 'ore expectant' below this level. For Gellivara, together with other mining-fields of Norrbotten, I came to the result of 200 M.T., to a total for Norrbotten of 500 M.T., and for the whole country 600 M.T., instead of Törnebohm's 1200 M.T.

In this year (1907) Professor W. Petersson has made an official statement of the ore quantities of some of the largest ore deposits of Norrbotten, founded chiefly on the records collected by the mining companies.

I shall have an opportunity later to refer to the statement of Professor Petersson, which on the whole was executed on a sound and conservative basis.

As to the Norwegian mining-fields, the records are very scanty. Professor Vogt has given a few figures about some of the ore deposits of the Norwegian south coast and of the ore province of Northern Norway. Furthermore, some figures given in commercial papers are obtainable but these must be used with very great caution.

After this general review I shall consider each ore province separately.

1. *Ore Province of Central Sweden.*

In this ore province we have one large ore deposit, Grängesberg, containing more than half of the obtainable ore and a number of smaller deposits. For Grängesberg we have two recent calculations of the ore quantity. The first, which was made by the mining engineer, Mr. Brunnberg, and published by Törnebohm in the year 1905, resulted in a figure of 60 M.T., reckoned to a depth of 300 metres. Later Mr. Hedberg published a new calculation. This resulted in a figure of 64 M.T. for the ore quantity between the surface and a depth of 350 m.: of this already about 12¼ M.T. are consumed, so that above the said level of 350 metres at least 51 M.T. will remain.

In the other mining-fields and the countless smaller mines scattered over this ore province, chiefly carrying ore low in phosphorus, from

ancient times up to the end of the nineteenth century about 60 M.T. of iron ore were mined. When comparing this quantity with the amount of 'ore expectant' still left in the mines, one arrives at the result that the remaining part may be estimated at most at 40 M.T. This corresponds with an additional sinking of the average level of all the mines 150–200 m., which is the greatest depth one can reckon upon in such a case.

A few words may here be said about the persistence of the Swedish ore deposits in depth. Since the mining of these ores has been carried on for centuries, we have a lot of experience on this question. In most cases the workable ore of a single deposit does not extend to a depth of 100 metres: this represents the great bulk of all the iron mines. Among the others only a few continue to depths between 100 and 200 metres, and the cases in which the ore could be followed to depths over 200 metres are easily counted. Only one mine has exceeded a vertical depth of 400 metres or reckoned along the pitch 500 metres.

It is not easy to give a geological explanation of this fact, but experience on this point speaks very clearly.

If we add 9 M.T. for ore reserves in old mines already abandoned but which possibly may to some extent be worked again, and for new finds, we arrive at an ore quantity in Central Sweden of—

	M.T.
Grängesberg	51
Other mines	40
Old abandoned mines and new finds	9
	100

2. *Ore Province of Norrbotten.*

In this ore province the ores were not worked to a noteworthy extent before the end of last century. In consequence thereof we have very little experience about the depths to which the deposits reach; also the mode of formation of the ores is doubtful. These circumstances make great caution necessary when attempting to estimate the ore supply, and it cannot be calculated at great and uncertain depths.

The most remarkable of the ore deposits of Norrbotten is *Kiirunavaara.* The deposit here forms a mountain ridge, rising to a height of 250 metres above the level of Lake Luossajärvi. It crops out for a length of 2·8 kilometres, with a width ranging up to 200 metres. The area of the outcrop is, according to the calculation of Professor W. Petersson, 286,000 square metres.

On account of its occupying the higher parts of a mountain ridge, the deposit is to a certain degree 'developed' by Nature. Several diamond drillings and a gallery have served to develop this part of the deposit still more, so that it may be considered as comparatively well known. Already Lundbohm, in the year 1897, estimated the ore supply above the level of the lake to be 215 M.T. This estimate was confirmed through the calculation made by Professor Petersson in 1907, who came to a figure of about 200 M.T. above the lake. In both these calculations it is reckoned with 4·5 tons of ore from the mined work, which I consider rather high, taking into consideration that this extremely pure ore also contains some parts of barren rock. Although I should prefer the figure 4 tons of

ore pro m^3 rock as more fair, I, with this reservation, accept the calculation of Professor Petersson.

About the ore quantities below the level of Lake Luossajärvi we know very little indeed. A few drillings have in some places proved the existence of ore at a depth of 200 m., but nothing is known about the length or width of the deposit on this level. Taking into consideration that in some places the hanging wall and the footwall seem to approach each other with increasing depth, it seems to me not allowable to add as 'ore expectant' more than half the amount of the ore above the level of the lake, *i.e.*, 100 M.T.

Gellivare is, in respect to magnitude, the second of the great iron deposits of Norrbotten. It gives an illustrative example of the way in which certain ore deposits have at first been over-estimated, and then, in consequence of more minute survey, have had their size reduced. As to the ore area, we have the following statements about Gellivare :—

	Hectares
In 1876 by the Geological Survey of Sweden	65
In 1890 by the Royal Commission for investigating the apatite deposits	44
In 1897 by Professor G. Nordenström	20
In 1907 by Professor W. Petersson	18·5

Thus during a period of thirty years the first estimate of the ore area has been reduced to less than a third. Experience proves that in Gellivare one may reckon on 2·9 tons of ore for every square metre of ore area sunk one metre, and from this it may be calculated that by an average sinking of the ore level to a depth of 150 m., about 80 M.T. should be obtained. Of this already about 13 M.T. have been mined, and the remaining 67 M.T. are then to be taken into account as 'ore expectant.' It may be that some of the deposits in Gellivare do not reach a depth of 150 m., but others among the numerous ore bodies will certainly be found to reach further down, thus averaging the differences.

There are in Norrbotten three more ore-fields of the same order of magnitude: *Ekströmsberg*, *Svappavaara*, and *Leveäniemi*; for each of these the ore area is stated to be about 50,000 m^2, but the statement is very uncertain. These ore-fields are not yet worked, lying far away from railway communications, and the ore supply is only known through surface workings, drillings, and magnetic surveys. Owing to the greater percentage of ore obtained from the mined rock at Ekströmsberg, one may count four tons of ore from every square metre sunk, and 3·5 tons per square metre from Svappavaara and Leveäniemi. This gives for a depth of 150 m. 30 M.T. for Ekströmsberg, and about 55 M.T. for the two others.

In the vicinity of Kiirunnavaara two smaller ore deposits occur, being of the same nature as this one. One is Luossavaara, the other *Tuolluvaara*; only the latter has, as yet, been worked. The ore area of Luossavaara is about 50,000 m^2, that of Tuolluvaara much smaller.

The ore quantity of Luossavaara was in 1897 estimated at 18 M.T., and by Professor Petersson, in 1907, at 22·5, both calculating only the ore above the level of Luossajärvi. I think it will be safe to reckon 20 M.T. as an average between the two figures for Luossavaara and for Tuolluvaara, together with other small deposits near Kiiruna, perhaps 8 M.T.

There are also several smaller deposits scattered over this ore province

about which too little is known in respect to the ore quantities to make it possible to give any details. Among these is *Mertainen*, with an ore area stated to contain 10,000 m^2. If we put all these ore deposits at 20 M.T. we get a round figure for the whole ore quantity in Norrbotten of 500 M.T., viz. :—

	M.T.
Kiirunnavaara	300
Gellivare	67
Ekströmsberg	30
Svappavaara and Leveäniemi	55
Luossavaara	20
Tuollavaara	8
Mertainen and other smaller deposits	20
Total	500

3. *Ore Province of Northern Norway.*

Here we are on more uncertain ground than in the preceding case, not only because very few attempts have been made to arrive at a true conception of the ore quantities in separate ore districts, but also because the experience won in the practical mining of this kind of ores only dates from the last few years. Thus we know nothing about the depth to which the workable ores reach

These ores occur, as stated above, in the metamorphosed Cambro-Silurian schists together with limestone. They show in many places an extension of several kilometres in length, and at the same time a considerable thickness. If one regarded these ores as ordinary stratified formations, only altered by regional metamorphism, one would have to assume an extent of several kilometres also in the direction of the dip. But such a conclusion might be highly misleading with regard to the ore supply. The possibility that these ores are secondary concentrations in the higher zone must be kept in mind, and, consequently, it does not seem allowable to calculate to any great depths before we have gained a wider experience in this point.

As already stated, these ores are in general very lean, and they often go below the limit of being workable. As they cannot be smelted directly, they must first be treated by magnetic concentration, and in this process the non-magnetic part of the iron, *i.e.*, hematite, iron silicates, &c., is lost. From such ores, showing by analysis 40 per cent. of iron, only 20 per cent. or a still less percentage may be utilised. Often the ore deposits, though extensive in the direction of the strike, are narrow, or when thicker they contain barren country rock to such an extent that the cost of mining will be too expensive. In many cases it seems difficult to trace the limit between ore and iron-bearing rock, which circumstance, of course, makes the estimation of the ore quantity highly speculative. On the other hand, the concentrated ore in the form of an easily reducible briquette, with 65 per cent. to 68 per cent. of iron, and practically without sulphur and phosphorus, is a very valuable product which will, when produced on a large scale, become a factor of great importance for the iron industry of Western Europe.

Dunderland is the greatest ore-field of this province. The ore area was estimated by me in the year 1894 at one million square metres in round numbers. In 1899 Mr. Hasselbohm calculated it still higher, viz., 1,290,000 m. Starting from the first-mentioned size of the ore area, and

calculating 2·1 tons of crude ore in the cubic metre, we arrive at a figure of 315 M.T., or, in round numbers, 300 M.T. for a depth of 150 m., which depth, as an average, corresponds with the level of the Dunderland River.

It is calculated that in the central part of the ore-field, where stoping is now going on, about 89 M.T. could be obtained by open pit workings on an area of 575,000 m.

The amount of ore in Dunderland would thus be about as great as is Kiirunnavaara. But it must be remembered that the ores are of very different quality, the Kiirunnavaara ore averaging 65 per cent. iron, the Dunderland ore, on an average, not reaching 40 per cent. Fe, of which only a part can be extracted.

Among the other numerous ore-fields of the same class, *Salangen*, *Ofoten*, and *Rollö* probably contain the largest ore quantities. These fields have not been sufficiently investigated to make an estimate of the ore quantities possible ; but the ore-bearing strata are very extensive, and may in each case be followed for kilometres in length. New ore deposits of this kind are found every year, and it seems certain that one may count on very great quantities. As a first approximation I venture to say that all these ore-fields together may contain at least half the amount of Dunderland, *i.e.*, 150 M.T. in round numbers.

For the ore province of Northern Norway we thus get :—

	M.T.
Dunderland (to a depth of 150 m.)	300
Other deposits	150
Total	450

4. *Ore Province of the South Coast of Norway.*

This province contains a number of deposits, some of which were worked in very ancient times ; most of them are comparatively small. Vogt has given figures for the ore area of some of the districts, viz. :—

	M^2.
The Arendal district	5000
The Kragero	2000–5000
The Nissedal	1400

The ore deposits are of the same nature as in Central Sweden ; many of the mines have already been abandoned at a comparatively small depth. If we put the ore quantity at 10 M.T., this figure is the highest one may venture for the whole province.

5. *Ore Province of Syd-Varanger.*

The deposits of this ore province were discovered only a few years ago, and only exploratory work has as yet been executed there. The deposits have a very great extension both in length and width. Mr. Nordensten recently estimated the ore area in this district at more than one million m^2. Calculating 3·6 tons of ore for each cubic metre, he estimates the ore quantity in the Bjornvand field alone, the central part of the district, to be 112 M.T. above the level of the sea. In all one may count on 400 M.T. above the sea-level in this ore province.

Contents of the Ore expressed as Pig Iron.

As already pointed out, the figures expressing the ore quantities of the different ore provinces are not directly comparable; thus, for instance, the ores in the ore province of Norrbotten, *i.e.*, those of Kiirunnavaara, Gellivare, &c., generally contain about 65 per cent. of iron; the ores from the ore province of Northern Norway in general hardly reach 40 per cent., of which only a part can be extracted. For the purpose of comparison we may express the quantity of iron in the ore as pig iron.

The majority of the iron mines of Central Sweden yield an ore giving about 50 per cent. pig iron; only the greatest deposit, Grängesberg, produces a richer ore corresponding to 62 per cent. of pig iron. On the whole, for the ore province of Central Sweden we may calculate on 55 per cent. of pig iron from the ore. For the ore province of the south coast of Nroway the same figure as for the majority of mines in Central Sweden, *i.e.*, 50 per cent., may be true.

The ore province of Norrbotten produces ore still richer in iron. The greatest deposit, Kiirunnavaara, yields an ore giving on an average more than 65 per cent. of pig iron, and the same may be said about Luossavaara and Gellivare. The ore from Svappavaara, Leveäniemi, and Ekströmsberg is less rich, but on an average we may calculate on 65 per cent. pig iron from the ores of this ore province.

The ores of the ore province of Northern Norway are all very lean ores. The experience in Dunderland is that it takes four tons of crude ore to produce one ton briquette, containing 65 per cent. to 68 per cent. Fe, which corresponds to about 16 per cent. pig iron from the crude ore. In Salangen and the other fields containing more magnetite the recovery will be better, and may be estimated at more than 25 per cent. pig iron from the ore. On an average, one may reckon on 25 per cent. pig iron from the mined ore in this province.

The ores of the ore province of Syd-Varanger are magnetic, thus giving better results, and a percentage of 33 per cent. of pig iron from the ore may in this case be assumed.

—	Ore Quantity in M.T.	Percentage of pig iron from the ore	Ore Quantity expressed as pig iron
			M.T.
Ore Province of Central Sweden . .	100	55	55
" " Norbotten . . .	500	65	325
" " North Norway . .	450	25	112·5
" " South Coast of Norway	10	50	5
" " Varanger . . .	400	33	132
Total	1460	—	629·5

In the above calculation the small deposits in the ore province of Christiania are not taken into account, as they seem to be without any commercial importance and not one of them is now worked. For the same reason the Lake and Bog ores, scattered over most provinces, are not taken into consideration. Also the large supply of iron contained in the titaniferous iron ores is not taken into account, though some of these deposits, as Taberg and Routivara, in Sweden, and the titanic ores in the

Ekersund-Soggendal district, in Norway, are among the largest iron deposits in Scandinavia. All attempts to utilise them either for the home manufacture or for export have hitherto failed because of the unfitness of the ores for metallurgical purposes, which is also the cause why all, or nearly all, other titaniferous iron ores all over the world lie unworked.

Qualities of the Ores.

The ores considered above differ in such qualities as determine their practical utilisation. From this point of view we may classify the ores into three classes, viz. :—

A. Bessemer ores, low in phosphorus.
B. Ores high in phosphorus, suitable for the basic processes.
C. Lean ores, too low-grade to be smelted without being subjected to magnetic concentration.

A. *The Bessemer ores* chiefly occur in the ore province of Central Sweden. They generally contain less than 0·05 per cent. of phosphorus, often less than 0·01, and only in this case they are considered as free from phosphorus. They originally amounted to about 100 M.T., but 60 M.T. have already been utilised, and the remaining 40 M.T. will last for the home manufacture only thirty years if ores of the same quality from Norrbotten are not utilised to a greater extent.

In the ore province of Norrbotten the supply of ore so low in phosphorus that it may be used as Bessemer ore is very limited. The ores most pure with regard to phosphorus, from Kiirunnavaara and Gellivare, generally contain from 0·017 per cent. to 0·028 per cent. of phosphorus, but the percentage of phosphorus is so variable that the seller does not guarantee less percentage than 0·05. Ore of the same quality also occurs in Luossavaara and Mertainen. This percentage is considered rather too high for the Swedish manufacture of steel by the acid process. Only in Tuollavaara an ore with a phosphorus percentage of 0·007–0·015 is mined, but the quantities are certainly limited.

The quantities of ore low in phosphorus available in the above-mentioned mines of Norrbotten are not yet possible to determine, but if we go as high as to 0·05 per cent. of phosphorus, we may, as a first approximation, anticipate a quantity of 20 M.T. of this kind of ore. This quantity, together with the 40 M.T. in Central Sweden, is thus the only raw material suitable for the manufacture of acid process steel.

It has been considered of such importance that this limited ore quantity should really be available for the home manufacture, that the Swedish Government has in the agreement entered into this year with the Grängesberg Company made provisions against the export of this kind of ore.

B. *Ores high in Phosphorus, suitable for the Basic Processes.*—The bulk of the ore deposits in Norrbotten contains ore of this kind. The percentage of phosphorus varies from 0·05 per cent. to 3 per cent., and even more. Also in Central Sweden we have a large deposit of this class of ore, viz., Grängesberg, and several smaller deposits, containing, taken altogether, about 60 M.T.

Owing to the limited supply of ore low in phosphorus, the quantity of ores of this class which the Swedish iron industry consumes is every year increasing ; thus already now about a fourth of all the steel manufactured

in Sweden is made by means of the basic processes. Most of the ores rich in phosphorus are exported to Germany and England. The export in 1905 amounted to 3·3 M.T.

Also most of the ores in the province of the south coast of Norway are rich in phosphorus.

C. *Lean Ores.*—Though low-grade ores are met with in all ore districts, it is chiefly in the ore provinces of Northern Norway and of Syd-Varanger that it is predominating. Owing to the low percentage of iron, the ore must be subject to magnetic concentration before being smelted. This class of ore has not yet been utilised for the home manufacture either in Sweden or in Norway. Preparations are going on for exporting it on a large scale, not only from Dunderland, but also from the ore-fields of Ofoten, Salangen, and Syd-Varanger. The ores of Dunderland contain about 38 per cent. of iron, mostly as hematite; the percentage of phosphorus is on an average 0·2. Through magnetic concentration it will be possible to reduce the phosphorus very considerably, and to export a briquetted ore containing about 65 per cent. of iron and only 0·016 per cent. to 0·026 per cent. of phosphorus.

For meeting the demand of iron ore in the western part of Europe this source of ore will in the next year without doubt become of very great importance.

The above review gives the following result:—

	M.T.	M.T.
A. *Ores low in Phosphorus.*		
Central Sweden	40	
Norbotten	20	
		60
B. *Ores high in Phosphorus.*		
Central Sweden	60	
Norbotten	480	
South Coast of Norway	10	
		550
C. *Low-grade Ore.*		
Northern Norway	450	
Varanger	400	
		850
Total		1460

I will conclude with a few words about the ore politics of Sweden, which has caused some alarm in the countries in demand of iron ores. In respect to abundant iron ore supplies, the Scandinavian Peninsula has been richly provided by Nature, but at the same time the lack of fuel makes it difficult to utilise the ores for the home industry. Owing to that, an export of iron ore has arisen during the last twenty years, but it was always the aim of the Government and of the leading parties of the Riksdag to confine this export within certain limits. Thus, when in the year 1898 the railway from Gellivare to the port of Narvik was to be built for the purpose of opening up the ore province of Norrbotten, and putting the largest ore deposit of Sweden in communication with a port on the Atlantic coast, the necessary means were voted by the Riksdag only on the condition that the ore exported on this railway, *viâ* the port

of Narvik, should not exceed 1·2 M.T. a year. Later on, when one single company—the Grängesberg Company—had managed to control nine-tenths of the ore supplies of Sweden, and the annual export of ore exceeded 3 M.T., a strong movement for laying an export duty on iron ore arose.

In the meantime several new investigations of the supplies of the larger deposits had been made, and these having shown that an increase of the export could be allowed without any danger of a premature exhaustion of the deposits, an agreement between the Government and the Grängesberg Company was made, which was this year confirmed by the Riksdag.

According to this agreement the Grängesberg Company was allowed to export up to 3·5 M.T. in the year by way of the port of Narvik, but the company became subject to several severe conditions. Thus the company had to allow the State to enter as a shareholder for half the amount of the joint capital without any payment, and, furthermore to give over to the State all the rights to the mines of Luossavaara, Ekströmsberg, and Mertainen, representing, according to the above calculations, more than 50 M.T. of ore. In the year 1932 the State will have the right to buy also the other mines on certain terms. During the period of twenty-five years from 1907 to 1932 no more than 75 M.T. may be exported from Kiirunnavaara, and no more than 18·75 M.T. from Gellivare. If the State should make use of its right to buy the mines in 1932, the company must prove that at that time there are left at least 150 M.T. in Kiirunnavaara, and at least 37·5 M.T. in Gellivare. In order to guarantee the home manufacture the necessary ore supply, it is provided in the agreement that the export of ore low in phosphorus from certain parts of Kiirunnavaara shall be prohibited, and that the export of ore from Grängesberg has to be gradually reduced.

It may be thought surprising that a country without coal supplies should be so anxious to save the ore deposits necessary for a great iron industry. But in Sweden we look forward with confidence to the time when we may utilise our peat mosses and our water power for electrical smelting in the metallurgy of iron. This time may be remote, but it will certainly come. The peat mosses in Sweden only are estimated at 5,000 M.T. dry peat, corresponding to about 2,500 M.T. of coal. And the water power available for electrical energy is practically unlimited.

The Fossil Flora of the Transvaal.—Report of the Committee, consisting of Professor J. W. GREGORY *(Chairman)*, Professor A. C. SEWARD *(Secretary), and* Mr. T. N. LESLIE, *appointed 'to enable Mr. T. N. Leslie to continue his Researches into the Fossil Flora of the Transvaal.'*

MR. T. N. LESLIE has made further collections of plants from the lower Karroo beds of Vereeniging, and these have been described in a joint paper by Professor A. C. Seward and Mr. Leslie. It is hoped the paper will be published during the coming winter.

The Committee do not ask for reappointment.

Occupation of a Table at the Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Professor A. SEDGWICK, *and* Professor SYDNEY H. VINES.

ONLY one application for the use of the Association's table at Plymouth has been received during the year. This was from Mr. A. D. Darbishire, who wished to investigate the function of the spiracle in elasmobranch fishes. Mr. Darbishire occupied the table for about a week at Easter, and the results of his investigations have been incorporated in a paper which he communicated to the Linnean Society on May 2.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor S. J. HICKSON (*Chairman*), Rev. T. R. R. STEBBING (*Secretary*), Sir E. RAY LANKESTER, Professor A. SEDGWICK, Professor W. C. MCINTOSH, *and* Mr. G. P. BIDDER.

THE Committee report that the Association's table at Naples was occupied during the Easter vacation by Dr. W. N. F. Woodland and by Mr. R. W. H. Row. The reports of these investigators are appended.

The Committee desire to be reappointed and ask for the requisite grant of 100*l*.

Report of Dr. W. N. F. WOODLAND.

During my three weeks' occupancy of the British Association table at the Naples Zoological Station, I was for the most part engaged in properly preserving material for investigations in connection with the brain (the structure of the pituitary body in particular), scale-development and cartilage-calcification in fishes generally, and with the 'red-bodies' of teleosts. I carried out numerous experiments in order to ascertain the precise mode of circulation of the cerebro-spinal fluid in the common dogfish, but I was not able to obtain results as accurate as I could wish. I also in my spare time ascertained and made drawings of the general distribution of the cranial and anterior spinal nerves of the Angler fish (*Lophius piscatorius*).

I beg to express my thanks to the Committee for the use of the table.

Report of Mr. R. W. HAROLD ROW.

During my occupancy of the British Association table at Naples Zoological Station last Easter, I was chiefly occupied in collecting and preserving Amphioxus material for investigations on the Nephridia.

In my spare time I dissected the cranial and anterior spinal nerves of *Squatina fimbriata* and *Trigla* sp.

I desire to express my thanks to the British Association Committee for the opportunity so kindly provided me.

Index Generum et Specierum Animalium.—Report of the Committee, consisting of Dr. HENRY WOODWARD (*Chairman*), Dr. F. A. BATHER (*Secretary*), Dr. P. L. SCLATER, Rev. T. R. R. STEBBING, Dr. W. E. HOYLE, Hon. WALTER ROTHSCHILD, *and* Lord WALSINGHAM.

THE indexing of the literature for the second portion of this Index (1801-1850) has steadily progressed. Among the works included are :—

'Archiv für Bergbau,' &c., 43 vols.
'Archiv für die gesammte Naturlehre,' 27 vols.
'Archiv für Naturgeschichte,' 16 vols.
'Athenæum,' 23 vols.
Basel, 'Naturforschende Gesellschaft,' 8 vols.
Batavia, 'Batav. Genootsch.,' 16 vols.
'Beiträge zur Petrefactenkunde' (Muensters).
Berlin, 'Gesellschaft naturforschende Freunde.'
Berlin, 'Bericht und Abhandlung k. pr. Akad. Wiss.,' 50 vols.

Also the writings of Audouin, Audebert, Audubon, Audinet, and Bechstein, a list which might be considerably extended.

The accumulated results of three years' recording have now all been arranged and sorted under their respective genera, and therefore one set of entries is now available for reference by monographers so far as recording has proceeded. The duplicate set of entries has been partially arranged; and further accommodation, provided by the kindness of Dr. Smith Woodward in the Geological Department of the British Museum (Natural History), has greatly relieved the pressure arising from the steady growth of material.

The Committee ask for reappointment, and hope that a grant of 100*l.* will be given for the further preparation of the 'Index Animalium' by Mr. C. Davies Sherborn.

Experiments on the Development of the Frog.—Report of the Committee, consisting of Professor G. C. BOURNE (*Chairman*), Dr. J. W. JENKINSON (*Secretary*), *and* Professor S. J. HICKSON. (*Drawn up by the Secretary.*)

On the Relation between the Symmetry of the Egg and the Symmetry of the Embryo in the Frog.

For a satisfactory solution of this problem it is necessary to determine quantitatively, and to express in statistical form, the relative positions in the egg of (1) the meridional plane which includes the sperm path; (2) the plane of symmetry of the unsegmented egg; (3) the first furrow of segmentation, and (4) the sagittal plane of the embryo. It is not possible to observe directly the relation between the first and fourth in one and the same egg, since all trace of the sperm path is lost by the time that the dorsal lip of the blastopore has appeared, but the angles between the first three or the last three may readily be measured in each of any number of eggs.

In the report presented to Section D at the York Meeting, the results of some such measurements were communicated. These results showed (1) that there was a tendency for the first furrow and the sagittal plane to coincide, though no correlation or causal connection could be demonstrated between them; (2) that there was a much stronger tendency for the sagittal plane to lie in the plane of symmetry of the unsegmented egg, and a considerable correlation between them; while (3) the first furrow tended either to coincide with or to lie at right angles to the place of symmetry.

This statement is however not final, for the possibility of a disturbing influence being exerted by certain external factors has still to be taken into consideration. The factors in question are: (1) the mutual pressures exerted by the jelly-membranes, and (2) the position occupied by the freshly laid egg. With regard to the first, it is well known that the direction of the first furrow may be determined by pressure; and as far as the second is concerned it is possible that gravity may act upon the semi-fluid contents of the egg during the short interval (half a hour) which elapses before the definitive position, with the axis vertical, is assumed.

These possibilities have now been experimentally tested, and it has been found in the case of the angle between first furrow and sagittal plane that

(α) When the axis is originally vertical, and the eggs spaced, the standard deviation is $\sigma=30{\cdot}94\pm{\cdot}71$ ($n=426$).

(β) When the eggs are spaced but the axis horizontal $\sigma=31{\cdot}28\pm{\cdot}90$ ($n=281$).

(γ) When the axis is vertical, but the eggs closely packed $\sigma=33{\cdot}65\pm{\cdot}56$ ($n=793$).

(δ) When the axis is horizontal and the eggs packed together $\sigma=37{\cdot}79\pm{\cdot}69$ ($n=683$).

It is evident that both these factors interfere with the 'typical' relation between first furrow and sagittal plane, for when both are removed the tendency of the two to coincide increases markedly.

The value obtained for the standard deviation when both factors exist is approximately the same as that obtained from last year's measurements when disturbing influences were not allowed for, viz., $\sigma=40{\cdot}39\pm{\cdot}64$.

At the same time it should be pointed out that in a state of Nature the eggs are laid with their axes making all angles with the vertical and subjected to the mutual pressures of their jellies in the bunch. Probably, therefore, in 'normal' development the correlation between first furrow and sagittal plane is very slight if not zero. The correlations in each of the above four experiments remain to be worked out.

Colour Physiology in Animals.—Report of the Committee, consisting of Professor HICKSON (*Chairman*), Dr. F. W. GAMBLE (*Secretary*), Dr. W. E. HOYLE, *and* Dr. F. KEEBLE, *appointed to enable Drs. Gamble and Keeble to conduct Researches on the relation between Respiratory Phenomena and Colour Changes in Animals.*

DURING the summer of 1906 Drs. Gamble and Keeble, working at Trégastel, Brittany, completed their joint investigation of the green cells in the worm *Convoluta roscoffensis*. A full account of the results of this research has appeared in the 'Quart. Journ. Micros. Science' (vol. li., May 1907, pp. 167–219, pls. xiii. and xiv). In this paper the structure and life-history of the zoochlorellæ, the changes which these bodies undergo within *Convoluta*, and the physiological significance of this association are dealt with at length. The authors conclude that this green cell or infecting organism is a probably new species of Chlamydomonad alga exhibiting more primitive features than those of its nearest ally, the fresh-water genus *Carteria*. It is not only able to utilise for its metabolism such organic nitrogen compounds as urea and uric acid, but thrives better in such solutions than in the presence of nitrates only. It is capable of a saprophytic as well as of a holophytic mode of life, and under the former conditions exists in both colourless and green forms.

The association of this plastic infecting organism with *Convoluta roscoffensis* is traced by the authors to its hunger for organic nitrogen, such as is afforded by the egg-capsules of the worm and by the tissues of the young *Convoluta*. In the absence of the infecting organism *Convoluta* soon after hatching ceases to ingest protophytes and to grow. In the presence of this organism *Convoluta* becomes more translucent and grows rapidly. The excretory organs (protonephridia) so characteristic of other *Turbellaria* are here absent, and the authors conclude that the green cells function as an excretory system in *Convoluta*.

The fission-products of the green cells that are first ingested by the young *Convoluta* become mere assimilative corpuscles. Their nucleus degenerates, their membrane disappears. They furnish the carbohydrate required by the animal tissues in a soluble form. Gradually the animal becomes parasitic upon them, and in the subsequent struggle on the part of both animal and plant to obtain sufficient nitrogen the green corpuscles are ingested by the phagocytes.

An extension of this investigation to other cases of 'symbiosis' has been carried out during the past year. An allied form, the brown *Convoluta paradoxa*, was bred in fair numbers, and it was shown, contrary to the statements of von Graff, that the pigmented corpuscles of the egg do not give rise to infection of the young animal. Infection by a brown cell occurred sporadically in a few animals hatched from clutches of eggs laid in unfiltered sea-water to which algæ were added. Efforts to isolate and cultivate this brown organism were, however, begun too late to give a successful result.

This report concludes the joint work of Dr. Gamble and Dr. Keeble. The investigations on the xanthellæ or chlorellæ of Actinians, of Hydra, and of other Turbellaria than Convoluta, as well as the research on the pigment cells of Crustacea, are now being investigated by these authors working separately. For this reason the Committee do not ask to be reappointed.

Development of the Sexual Cells.—Interim Report of the Committee, consisting of Mr. J. J. Lister (*Chairman*), Dr. H. W. Marett Tims (*Secretary*), Mr. J. Stanley Gardiner, *and* Mr. G. H. F. Nuttall, *appointed to enable Dr. H. W. Marett Tims to conduct experiments with regard to the effect of the Sera and Antisera on the Development of the Sexual Cells.*

A series of experiments have been made with guinea-pigs to test the effects of testis extract on the normal Spermatogenesis and Oögenesis, and incidentally on the leucocytes.

The injections have been intra-peritoneal, and extending over varying lengths of time.

The histological investigations are not sufficiently complete to warrant publication, though so far as they have gone they seem to point to definite effects.

Guinea-pigs have been selected for investigation for two reasons (*a*) the large size of the testis-cells, and (*b*) the *normal* Spermatogenesis in the guinea-pig has been described in detail, and figured by J. E. S. Moore, Walker, and others.

Zoology Organisation.—Interim Report of the Committee, consisting of Sir E. Ray Lankester (*Chairman*), Professors S. J. Hickson (*Secretary*), G. C. Bourne, T. W. Bridge, J. Cossar Ewart, M. Hartog, W. A. Herdman, *and* J. Graham Kerr, Mr. O. H. Latter, Professor E. A. Minchin, Dr. P. C. Mitchell, Professors C. Lloyd Morgan, E. B. Poulton, *and* A. Sedgwick, Mr. A. E. Shipley, *and* Rev. T. R. R. Stebbing.

The Committee report that no meetings have been summoned during the past year.

There are some important matters at present under the consideration of the Committee, which render it desirable that they be reappointed.

The Investigation of the Oscillations of the Level of the Land in the Mediterranean Basin.—Interim Report of the Committee, consisting of Mr. D. G. Hogarth (*Chairman*), Mr. R. T. Günther (*Secretary*), *and* Drs. T. G. Bonney, F. H. Guillemard, J. S. Keltie, *and* H. R. Mill.

The work for which this Committee was appointed is proceeding, and in presenting this interim report the Committee ask to be reappointed, with the allotment of the unexpended balance of the grant.

Mr. Günther left England for Southern Italy as soon as possible after the expiration of the summer term in Oxford, with the intention of examining certain maritime sites in Calabria in connection with the work of this Committee. It will not be possible to submit any report on the results until the meeting of the Association in 1908.

Investigations in the Indian Ocean.—Second Report of the Committee consisting of Sir JOHN MURRAY (*Chairman*), Mr. J. STANLEY GARDINER (*Secretary*), Captain E. W. CREAK, Professors W. A. HERDMAN, S. J. HICKSON, *and* J. W. JUDD, Mr. J. J. LISTER, Dr. H. R. MILL, *and* Dr. D. SHARP, *appointed to carry on an Expedition to investigate the Indian Ocean between India and South Africa in view of a possible land connection, to examine the deep submerged banks, the Nazareth and Saza de Malha, and also the distribution of marine animals.*

THE Committee record with deep regret the death of Dr. Simpson, surgeon on board H.M.S. 'Sealark,' who undertook the collections and preservation of the land plants obtained by the expedition.

The Committee have received the following report from Mr. J. Stanley Gardiner, who has had charge of the work :—

Work has proceeded regularly during the past year on the collections obtained by the expedition. The dredged and reef-living animals have been sorted, and so far the following groups have been sent out for determination : Sponges (Professor A. Dendy), Hydroids (Dr. Marrett Tims), Stylasteridæ (Professor S. J. Hickson), Actiniaria (Mr. J. A. Clubb), Antipatharia (Mr. C. Forster Cooper), Madreporaria (Mr. J. Stanley Gardiner), Alcyonaria (Professor J. Arthur Thomson), Pennatulidæ (Professor S. J. Hickson), Turbellaria (Mr. F. F. Laidlaw), Nemerteans (Mr. R. C. Punnett), Gephyrea (Mr. W. F. Lanchester), Chætopoda (Mr. F. A. Potts), Cephalopoda (Dr. W. E. Hoyle), Shelled Mollusca (Mr. J. Cosmo Melvill), Nudibranchs (Sir Charles Eliot, K.C.M.G.), Cirripedes (Professor A. Gruvel), Isopoda (Rev. T. R. R. Stebbing), Amphipoda (Mr. A. O. Walker), Stomatopoda and Prawns (Mr. L. A. Borradaile), Alphæidæ (Professor H. Coutière), Crabs (Miss Rathbun), *Macrura anomala* (Professor G. Nobili), Pycnogonida (Professor G. H. Carpenter), Actinogonidiate Echinoderms (Professor Jeffrey Bell), Holothurians (Sir Charles Eliot, K.C.M.G.), Tunicata (Professor W. A. Herdman), Enteropneusta (Professor G. W. Spengel), and Fish (Mr. C. Tate Regan). The Lithothamnia have been undertaken by Dr. M. Foslie, and the rest of the Algæ by Mr. and Mrs. Gepp.

The pelagic or plankton animals have likewise been sorted out for specific determinations, and the following groups arranged for : Medusæ and Siphonophora (Mr. E. T. Browne), Turbellaria (Mr. F. F. Laidlaw), Copepoda (Dr. Morris Wolfenden), Schizopoda (Mr. Holt and Mr. Tattersall), Decapoda (Mr. Kempe), Amphipoda (Mr. A. O. Walker), Cephalopoda (Dr. W. E. Hoyle), Tunicata (Professor W. A. Herdman), Amphioxides (Mr. E. S. Goodrich), and Fish (Mr. C. Tate Regan).

So far no arrangements have been made for Spiders and Gammasids among land animals, and Polyzoa, Foraminifera, and Brachiopods among dredged forms. There are also the following large collections of pelagic animals : Chætopoda, Chætognatha, Heteropoda, Pteropoda, Ostracoda, and Protozoa. There are in addition about a hundred bottles containing material which was collected by nets of 180 meshes to the inch for

unicellular algæ. I should be glad to hear of any specialists interested in these groups.

During the course of the year papers were published on 'The Indian Ocean' and the 'Seychelles Archipelago' in the 'Journal of the Royal Geographical Society,' October and November 1906, and February 1907. The full series of reports has been undertaken by the Linnean Society for their 'Transactions.' Reports have been read before the Society and are now in the Press on the Land Nemerteans (Mr. R. C. Punnett), Land and Freshwater Crustaceans (Mr. L. A. Borradaile), Hymenoptera (Mr. P. Cameron), Ants (Professor A. Forel), Dragon-flies (Mr. F. F. Laidlaw), Pycnogonida (Professor G. H. Carpenter), Aves (Dr. Gadow and Mr. J. Stanley Gardiner), Lithothamnia (Dr. Foslie), Stomatopoda (Mr. L. A. Borradaile), Coccids (Mr. E. E. Green), Ticks (Professor Neumann), and Fishes (Mr. C. Tate Regan).

The above papers show that the expedition has secured a very large number of new species and genera in each of the classes of organisms collected. Of 184 species of fish fifty-three are new, and include representatives of no fewer than eight new genera. Most authors have as far as possible attempted to give the geographical distributions of the species, genera, and families they have dealt with. Among land animals these are at once of some value, but conclusions as to the geographical distribution of marine animals can scarcely be attempted until the working-out of the majority of the divisions of those forms is completed. To the same time also must be deferred the consideration of the question as to how far the distribution of marine animals throws light on the former connections of lands. A general account of the whole expedition (J. Stanley Gardiner and C. Forster Cooper), giving an account of much of the geographical work, is prefixed to the series of reports now being issued.

Geographically the Seychelles Archipelago was the most important area visited by the expedition. Its islands are all formed of granite, a rock which is otherwise peculiar to continental areas. They possess a very small vertebrate fauna, entirely pre-mammalian. Its most important forms are Cœcilians, a large species of tortoise, probably the same as is now found in Aldabra, and a crocodile. Unfortunately these last two are now extinct, but the islands should be explored for their remains. Their plants are mostly peculiar, but possess both African and Indian affinities. The same, too, is true of most groups of invertebrate animals. Of their insects we appeared to have a fair knowledge before the expedition went to the group, regarding its islands as purely oceanic. The collections of the expedition were mainly made in the indigenous jungle, and give indications of adding a very large number of new forms. For instance, Mr. Cameron's report on the Hymenoptera shows twelve new species and one new genus, exactly doubling the species known from the group.

The Seychelles must be considered of great importance in view of the supposed former connection between India and South Africa. To elucidate this, its land animals require to be known as accurately as possible. The indications so far point to a peculiar insect fauna, only a few forms of which—to judge by the analogy of the Hawaiian Islands—have as yet been obtained. Perhaps this is due to the fact that the expedition visited the archipelago in a time of drought. In any case a further exploration from this side would now seem imperative. There would

seem, too, to be no time to be lost, as there are less than three square miles of the indigenous jungle left, and it is daily being encroached upon

The expedition had actually only seven weeks in the Seychelles, and hence its work was necessarily of rather a scrappy nature. It is now felt that further explorations are also desirable in respect to the elevations of the islands and to the reefs round their shores, which were shown in the first report of the Committee to be of peculiar nature.

I would venture in conclusion to suggest the reappointment of the Committee, with a substantial grant to continue the geographical researches into the origin of the Seychelles Archipelago and the distribution of animals and plants.

Rainfall and Lake and River Discharge.—Interim Report of the Committee, consisting of Sir JOHN MURRAY (*Chairman*), Professor A. B. MACALLUM *and* Dr. A. J. HERBERTSON (*Secretaries*), Professor W. M. DAVIS, Professor P. F. FRANKLAND, Mr. A. D. HALL, Mr. N. F. MACKENZIE, Mr. E. H. V. MELVILLE, Dr. H. R. MILL, Professor A. PENCK, Dr. A. STRAHAN, *and* Mr. W. WHITAKER, *appointed to investigate the Quantity and Composition of Rainfall and of Lake and River Discharge.*

THE preparation of the bibliography continues, and it is hoped that it will be ready next year. Meanwhile special attention may be called to a paper by Dr. R. Fritzsche in the 'Zeitschrift für Gewässerkunde,' vol. vii., part 6, pp. 321–370; 'Niederschlag, Abfluss, und Verdunstung auf der Landflächen der Erde.'

The Committee understand that an investigation into the relationship between rainfall and run-off is being carried out under the direction of Dr. Aubrey Strahan, F.R.S., with grants from the Government Grant Committee and the Research Department of the Royal Geographical Society.

The Committee ask for reappointment, and a renewal of the grant made last year.

Amount of Gold Coinage in Circulation in the United Kingdom.—Interim Report of the Committee, consisting of Mr. R. H. INGLIS PALGRAVE (*Chairman*), Mr. H. STANLEY JEVONS (*Secretary*), *and* Messrs. A. L. BOWLEY *and* D. H. MACGREGOR.

THE Committee have obtained all the necessary data for estimating the amount of the gold coinage in circulation. These include returns from 698 branches of banks, each stating the dates found on 200 sovereigns and 200 half-sovereigns selected at random from the banks' tills about the middle of February 1907. The Bank of England and many of the most important banks of the country have kindly furnished valuable information regarding the date and quantity of unmixed coin in their reserves. The reduction of the returns is proceeding. It is found that sovereigns of 1906 date form 13·5 per cent. of the whole circulation of sovereigns. The returns show a very unequal distribution of new coin throughout the country, sovereigns of 1906 date varying from 50 per cent. in some parts of London down to less than 4 per cent. in certain agricultural districts

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Anthropometric Investigation in the British Isles.—Report of the Committee consisting of Professor D. J. CUNNINGHAM (*Chairman*), Mr. J. GRAY (*Secretary*), Dr. A. C. HADDON, Dr. C. S. MYERS, Mr. J. L. MYRES, Professor A. F. DIXON, Mr. E. N. FALLAIZE, Dr. RANDALL-MACIVER, Professor J. SYMINGTON, Dr. WATERSTON, Sir EDWARD BRABROOK, Dr. T. H. BRYCE, Dr. W. L. H. DUCKWORTH, Mr. G. L. GOMME, Major T. MCCULLOCH, Dr. F. C. SHRUBSALL, Professor G. D. THANE, Mr. J. F. TOCHER, Dr. W. MCDOUGALL, Mr. W. M. HELLER, Mr. C. M. STUART, Professor M. E. SADLER, Dr. W. H. R. RIVERS, Dr. W. D. HALLIBURTON, Mr. A. ABRAHAM, Mr. H. S. KINGSFORD, Mr. A. F. SHAND, *and* Mr. W. H. WINCH.

THE subjects which the Committee is called upon to deal with being so numerous and so diverse, it was deemed advisable to appoint five Sub-Committees, each of which would confine its attention to a particular branch of anthropometry and draw up a report to be submitted to the Committee as a whole. The following are the Sub-Committees which were constituted :—

1. An Anatomical Sub-Committee, consisting of the Chairman, the Secretary, Dr. F. C. Shrubsall (*Convener*), Dr. T. H. Bryce, Professor G. D. Thane, Dr. Waterston, Dr. W. L. H. Duckworth.

2. A Physiological Sub-Committee, consisting of the Chairman, the Secretary, Dr. W. McDougall (*Convener*), Dr. C. S. Myers, Dr. W. H. R. Rivers, Dr. W. D. Halliburton, Mr. A. F. Shand, Mr. W. H. Winch.

3. A Psychological Sub-Committee, consisting of the same members as the Physiological Sub-Committee.

4. A Photographic Sub-Committee, consisting of the Chairman, the Secretary, Mr. J. L. Myres (*Convener*), Dr. A. C. Haddon, Mr. G. L. Gomme, Dr W. L. H. Duckworth, Mr. A. Abraham, Mr. H. S. Kingsford.

5. An Educational Sub-Committee, consisting of the Chairman, the Secretary, Mr. E. N. Fallaize (*Convener*), Professor M. E. Sadler, Mr. W. M. Heller, Mr. C. M. Stuart, Dr. F. C. Shrubsall, Dr. C. S. Myers, Dr. W. H. R. Rivers, Sir Edward Brabrook.

The Reports which have been submitted by these Sub-Committees represent the work of the Committee for the past year. They were considered at a meeting of the Committee held in the Anthropological Institute on May 1, and after some emendation were finally approved and adopted. Instead of incorporating them into one more or less homogeneous Report, the Committee believes that it will be more advantageous to present them to the British Association in the separate form in which they were originally prepared.

Report of the Anatomical Sub-Committee.

During the year the Sub-Committee has completed the list of measurements of the human body, prepared standard sets of hair and iris colours, and drawn up a series of lists of dimensions and observations of graduated complexity to be recommended for use in schools

A. Chest Measurements.

After some consideration it was decided that the dimensions included in the list already published should be adhered to, but that further inquiry into the level at which chest measurements had been taken at various times and in different countries would be advisable.

As a result of this inquiry it would appear: That observations on the shape and the relative if not the actual dimensions of the chest have been made since the days of Hippocrates, circa 500 B.C. Extensive notes were made by Galen and Aretæus, circa 150 A.D., but after that no further information is available until the end of the eighteenth century, when Skoda and Laennec practically introduced to the medical world the modern procedure for the physical examination of the chest. These observers took tape measurements at the level of the xiphoid cartilage. (Laennec, 'Traité de l'Auscultation Médiate,' Paris, 1826, p. 21). The examination of the antero-posterior and transverse diameters by means of callipers and a flexible metal tube, the cyrtometer, fitted accurately to the chest, was introduced by Woillez. ('Recherches cliniques sur l'emploi d'un nouveau procédé de mensuration,' Paris, 1857.) He made his observations on normal chests apparently at the level of the sterno-xiphoid junction, but as his apparatus was designed primarily for the study of chests in which one side had been rendered asymmetrical by the presence of a pleural effusion, most measurements were taken over the point of maximum bulging. The same level was adopted by Gee, who studied the relation of the diameters by the use of callipers. The extensive series of observations made by Walshe and Cotton, and others by Hutchinson on the shape of the chest in relation to the vital capacity both in health and disease, were always taken at the junction of the sixth costal cartilage with the sternum. Sieveking, on the other hand, measured the circumference just above the nipples.

The level adopted for the measurement of recruits in this country is to place the tape over the nipples in front and immediately below the angles of the scapulæ behind, the arms being held above the head while affixing the tape, but being brought to the side before reading off the result. The levels adopted in the Continental armies appear to vary from the fourth costo-sternal junction to the fifth interspace. No record could be found that calliper measurements were taken as a routine in the examination of recruits or conscripts of any army.

Polanski, of Warsaw, took both transverse and antero-posterior diameters at the level of the nipple, and at points 4 centimetres above and below this. He later abandoned this, and recorded only the greatest diameters in either direction wherever found. ('Zeitschrift für Tuberculose,' Heft 5.)

A greater number of calliper measurements have been made in the United States, of which a *résumé* appears in an article by Lawrason Brown ('American Journal of the Medical Sciences,' October, 1904). Hutchinson chose the middle of the fourth intercostal space; Sargent, Seaver, Otis, Beyer, and Hrdlicka used the level of the nipples. Sack in Russia and Hoesch-Ernst in Zurich took the diameters at the level of the mid-sternum. The records of Pagliani, Axel Key, Erissman, Zak, and other Continental observers are from tape measurements at the nipple line. Topinard and Weisberger measured the diameters at the level of the lower end of the sternum. A wide range of variation in the method

adopted is thus seen to exist, and the comparison of the results of different observers is nearly impossible.

Lawrason Brown investigated a series of patients at the Adirondack Cottage Sanatorium to ascertain what variations might occur from the difference in level at which the measurements were taken. He found that the difference between the level of the junction of the fourth costal cartilage and the sternum and that of the nipples varied from 1 to 5 centimetres. Resulting from this the transverse diameter showed a variation of less than 1 per cent., while the antero-posterior diameter varied considerably from 3 per cent., being deeper at the nipple level.

A series of confirmatory observations made at the Brompton Hospital on male patients showed the difference in level between the fourth costal cartilage and the nipple line varied from 1·1 centimetre to 3·5 centimetres. The difference in level between the nipple line and the lower end of the sternum showed far greater variations, ranging from 3 to 9 centimetres, while in female patients the range was only from 1 to 2 centimetres for the upper levels, and 2 to 5 centimetres at the lower levels.

In one case (a child) the nipple line was actually upon the junction of the fourth costal cartilage with the sternum, and the distance from this line to the bottom of the sternum was 9 centimetres. The nipple line showed a tendency to vary across the level of the fourth and fifth interspaces.

Measurement of the diameters showed a steady increase from above downwards, but not so great a proportionate difference as would appear from the American results. The level which would seem to approximate most closely to the mean of those in constant use is that of the junction of the fifth costal cartilage and the sternum ; but, on the other hand, this cartilage is more difficult to find than the fourth.

Taking into consideration, therefore, the results of this investigation, with the methods adopted for chest measurement by other observers in this and other countries, the Anatomical Sub-Committee do not consider that there is any reason for departing from the original decision, viz., that the level at which these measurements should be taken is at the point of junction of the fourth costal cartilage with the margin of the sternum. They are inclined to regard, however, with greater favour the data obtained by calliper measurements of the mesial diameter and of the transverse diameter of the chest taken at the same level.

B. Hair Colours.

The colours proposed comprised the following shades: Fair, light brown, dark brown, black, and three shades of red—light, middle, and dark. A series of locks of actual hair have been collected corresponding to the above-mentioned shades, but it has been found that on keeping them a few weeks the hair showed a tendency to fade, and so was no longer an exact match with the hair of the head from which it had been derived. This suggests the possibility that, after all, a standard series of locks of hair might prove a fallacious guide. All efforts to reproduce these colours by means of colour photography, hand-painting, and the use of hair dyes proved still more unsuccessful.

A large series of locks of hair having been collected, it appeared that it would be possible to distinguish some thirty to forty distinct shades.

On closely examining the hair of the head of any individual, it was observed that different parts of the hair would have to be classified under different headings, so that an expression for the value of the whole *coiffure* rather than an individual lock must be sought for. This difficulty has been avoided by arranging the samples of hair in plaits, so that the effect of light reflected from them at different angles can be noted. The general definition of the colours of the hair corresponds to that given by Beddoe.

C. Iris Colours.

As regards iris colour, it was decided to adopt a scale with four divisions—blue, grey, neutral, and brown. Artificial eyes, corresponding to the scales of these divisions, have been obtained, but some difficulty exists in exactly defining the boundaries, and for this purpose the scale of artificial eyes used by surgical instrument makers contains some 150 to 200 different shades; so that, if thought advisable, a very exact scale of description could be adopted. This, however, would only be suitable for use in large laboratories. For field-work and use in schools the scheme of classification adopted above would appear preferable. The standard scale of eyes contains central examples of brown, grey, and blue. All eyes lighter than the standard should be classed as light brown and all eyes darker than the standard as dark brown, &c. A very dark blue eye on this scale should be classed as dark blue, and not as dark, the division into which it fell in Beddoe's scheme. The advantage of separating the class of light eyes into grey and blue is that it enables comparisons to be made with German observations. The French scale, on the other hand, prefers to recognise only two varieties of eye, light and dark.

D. Schedules.

A series of Schedules of proposed anthropometrical measurements for the use of schools have been drawn up:—

Schedule 1.

Stature.
Weight.

Schedule 2.

Stature.
Weight.
Hair and eye colours.

Schedule 3.

The foregoing, with the addition of the circumference of the chest.

Schedule 4.

The measurements in 2 and the diameters of the chest taken with callipers.

Schedule 5.

All the above, and also the length and breadth of the head.

Schedule 6.

All the preceding, with the breadth of the shoulders and that between the trochanters.

Schedule 7.

The foregoing and the height of the head.

Schedule 1 consists of measurements designed to show the progress of the individual child, and are those on which the greatest reliance is placed from the hygienic aspect. However, considerable risk of a false comparison may exist, since children belonging to different races or stocks differ at all ages, even in these dimensions.

In Schedule 2 the records of the hair and eye colour are included to enable some degree of racial comparison to be made. These colours appear to be the most important racial characters, easily measured in the British Isles.

Schedules 3 and 4 include measurements of chest, either by the tape or by the callipers; the calliper measurements are preferable because comparison can then be made with the adults of both classes. It would be advisable that these dimensions should be measured both at full inspiration and full expiration, and a record made of the resulting excursion.

Schedules 5, 6, and 7 include head measurements, which are important owing to the lack of information we possess at the present time as to the variations in this country.

Important results may also be anticipated from the opportunity thus afforded of comparing the various head-forms with the different degrees of mental efficiency.

In addition to the Schedules put forward, any school at which there are ample opportunities for investigation could adopt any or all of the measurements described in the Report for 1905. The Schedules are only suggestions as to what could be done with limited opportunities, and are in no wise intended to restrict investigation.

Report of the Psychological Sub-Committee.

The Sub-Committee invited the British Psychological Society to nominate two of its members to co-operate with the Sub-Committee. Mr. A. F. Shand and Mr. W. H. Winch, having been chosen by the Society for this purpose, have been accordingly co-opted by the Sub-Committee.

The list of mental characters drawn up by Mr. McDougall and embodied in the Report submitted at the York meeting of the Association has been discussed at two meetings of the British Psychological Society, and has been amended and extended by the Sub-Committee in the light of these discussions. The amended list is submitted with this Report.

The Sub-Committee recommend that the list should be printed, and that, before any use of it on a large scale is attempted, it should be issued to a limited number of specially qualified school-teachers, who should be invited to fill in the schedules of characters for groups of pupils with whom they are well acquainted. In this way, it may be hoped, some data may be obtained for the formation of an opinion as to the applicability and reliability of this method of procedure. From this point of view it appears especially important to secure independent returns from two or more teachers in regard to identical groups of pupils, as the degree of correspondence between two or more such independently made Reports referring to the same group of pupils would indicate the degree of objectivity of the Reports.

The Sub-Committee are of opinion that, though data of some value may possibly be obtained by the issue of the list of mental characters to school-teachers and others, the survey of mental characters cannot be satisfactorily carried out save by the aid of observers specially trained in the methods of mental measurement, who would make a series of measurements of the capacities of each individual according to a scheme which has yet to be drawn up; they recognise that the estimation of

mental characters is very much more difficult than that of physical characters, and that it is necessary to proceed in a tentative and experimental spirit. They would especially insist on the difficulty of fixing any common standard and of obtaining returns which shall have an absolute value and shall be comparable with one another, except in so far as returns can be based on exact measurements made by the methods of experimental psychology.

(Amended) Instructions to the Recorders.

Mental characters are named, numbered, and briefly defined in this Schedule.

The accompanying card bears a corresponding number of numbered spaces.

The Recorder should put the name of one subject (child, &c.) at the head of each card, and write in the space opposite each number one of the letters *A*, *B*, *C*, *D*, or *E*.

These letters imply the following opinion on the part of the observer in respect to the mental characters of corresponding numbers :—

A. High degree of development, intensity or strength of the character in question.

B. A degree of development distinctly above the average.

C. An average degree of development.

D. Degree of development distinctly below the average.

E. A marked deficiency of the character in question.

An average degree of development is to be taken to mean such as would be exhibited by about 50 per cent. of any large number of normal persons of the same age, race, and class, this 50 per cent. group being made up of those who in respect to this character are nearest the mean.

Classes *B* and *D* should contain about 20 per cent. each of any large number of normal subjects.

Classes *A* and *E* about 5 per cent. each.

The Recorder should fill in on each subject's card only those characters in regard to which he feels able to express a confident opinion, and should leave all other spaces blank.

It is suggested that the following procedure should be adopted whenever possible, especially by those reporting on school-children : A table of thirty-four columns, numbered according to the list of characters, should be made on a large sheet of paper, and under each number the individuals of the group observed should be entered in the order of development of the corresponding character (those considered equal being bracketed together). This should be regarded as a first rough approximation only. From time to time the observer should go over his table, amending the order of names in each column in the light of his later observations. If this process were repeated once a month or oftener throughout a year's intercourse with the group of individuals reported upon, it is probable that the final arrangement of each column would represent a great refinement upon the order first given.

The words in popular usage by which mental characters are described are in many cases of a negative character. In the following list such words have been avoided and positive characters only are named ; *e.g.*, laziness does not appear, because a high degree of laziness is the same character

as a low degree of industriousness, and may be expressed by putting the letter *E* after the corresponding number on the card.

Many of the words in popular usage express characters which are extremely complex resultants of a number of more elementary characters (*e.g.*, intelligence); such words have been avoided as far as possible, and the characters named below have been chosen as being relatively simple and elementary.

List of Mental Characters.

1. Power of 'observation' or sense-perception,

 (*a*) Accuracy.
 (*b*) Fulness (*i.e.*, degree to which attention is habitually given to objects of the outer world rather than to reflection and imagination).

2. 'Quickness' of apprehension in general.

3. Scope of apprehension (*i.e.*, capacity for apprehending complex relations and multiplicity of detail).

4. Intensity of application to mental tasks (*i.e.*, power of 'concentration' of attention; this may be taken to be inversely as the readiness with which attention is distracted from the task in hand by irrelevant objects and impressions).

 (*a*) Spontaneous or non-voluntary.
 (*b*) In virtue of effort of will.

5. Capacity for sustained application (*i.e.*, for sustaining and repeating concentration of attention upon given task='perseverance').

 (*a*) Spontaneous.
 (*b*) In virtue of effort of will.

6. Natural or spontaneous 'interests' (*i.e.*, interests in objects or topics for their own sake, not indirectly acquired by special training or through such influences as emulation or systematic reward and punishment).

 (*a*) Intensity.
 (*b*) Variety or width of field of interests.
 (*c*) Persistency of interests in particular topics and objects.

7. Native 'retentiveness' of memory as expressed, *e.g.*, by accurate reproduction of matter committed to memory by rote learning or by capacity for describing objects or events of no special interest previously observed.

 (*a*) Immediate, *i.e.*, as revealed after brief interval of few minutes only.
 (*b*) Continued, *i.e.*, as revealed after interval of twenty-four hours or more.

8. Systematic memory (*i.e.*, retention of facts in virtue of the apprehension of their connection with topics of special interest to the individual, or because systematically related with one another).

9. Selective memory—exceptional retentiveness for certain classes of impressions, or for facts about certain subjects.

10. Vividness and detailed accuracy of representative imagination (*i.e.*, power of recalling past sense-impressions in corresponding imagery).

11. Freedom and range of play of 'fancy' (*i.e.*, in popular speech—imaginativeness).

12. Purposive constructive imagination (*i.e.*, 'inventiveness,' or the power of bringing things together in imagination in relations in which they have not previously been experienced, under the guidance of the idea of some end to be achieved).

13. Power of 'logical inference' or reasoning.

14. Confidence in his own observations, judgments, and inferences.

15. Freedom of expression of feelings and emotions.

16. Liability to anger

(*a*) Readiness with which the emotion is excited ;
(*b*) Intensity of the emotion ;
(*c*) Duration of the emotion.

17. Fear.

(*a*)
(*b*) } Same as 16.
(*c*)

18. Curiosity.

(*a*)
(*b*) } Same as 16.
(*c*)

19. Joyousness.

20. Sympathy (the tendency to be moved by an emotion when the expression of it in another person is witnessed—*i.e.*, primitive sympathy).

21. Courage or resolution (*i.e.*, not mere absence of fear, but degree to which purpose is pursued in spite of pain, fear, opposition, and of difficulties foreseen).

22. Altruism (the tendency to put the welfare of others, individuals or the public, before one's own as a motive of action).

23. Egoism (the frequency with which the idea of one's self and its relations is the ruling motive in action and the mainspring of the emotions).

24. Conscientiousness (tendency for action to be controlled by general principles rather than by the immediate promptings of desire and emotion ; expressed, *e.g.*, in truthfulness, honesty in schoolwork, punctuality, and general trustworthiness).

25. Industriousness.

26. Sensitiveness to opinions of other individuals (*e.g.*, of teachers or schoolfellows) or to public opinion (this is not to be confounded with conscientiousness or with suggestibility).

27. Sociability (the finding of pleasure and satisfaction in the society of fellows).

28. Initiative (expressed, *e.g.*, in tendency to assume leadership in games, in class, &c.).

29. Masterfulness—the tendency to impose one's own will and opinions upon others.

30. Suggestibility—readiness with which opinions and beliefs are impressed by the expressions of other persons.

31. Competitive or emulative spirit.
32. Sense of ludicrous.
33. Æsthetic feeling.
34. Energy (*i.e.*, capacity for doing work without exhaustion):
    (*a*) Bodily work;
    (*b*) Mental work.

Report of the Sub-Committee on Photographic Records of Anthropological Data.

Racial characteristics are conveniently recorded by means of photographs. In every case the name, sex, age, and nationality (including tribe, clan, or group), and also the date and place at which the photograph was taken, should be recorded, and an identifying mark should be placed on every negative. The portraits which are of anthropological value are as follows:—

A. General Characteristics.

(*a*) A few portraits of such persons of each sex as may, in the opinion of the observer, best convey the special characteristics of the race as regards features and pose of body. These should be taken in the aspect which best displays those characteristics, and should be accompanied by a note directing attention to the special features shown in the photograph. It is desirable that some of these portraits should *not* be taken either strictly full-face or in strict profile. Very interesting series are afforded by whole families. Snapshot photography often gives more characteristic records of expression and pose than can be obtained by formal sittings before a stand-camera.

(*b*) Special photographs should be taken to record all characteristic deformations of the head, face, teeth, and other parts of the body; and all forms of tattooing and scarification should be recorded by photographs taken in the aspect which best displays the peculiarity. Scarifications almost always demand special sidelong illumination; tattooing also sometimes needs orthochromatic plates. It is occasionally necessary to enhance tattoo marks with black paint on the person; but this should be avoided if possible.

B. Portraits of Head and Face only.

(*a*) The portraits should show in each case the left side of the face in exact profile. At least twelve male adults and twelve female adults should be photographed. The hair should be so arranged as fully to show the ear, and the males should be beardless if possible. If time only admits of a smaller number, or of only one sex, males should be preferred. To obtain the best average definition, the image should be focussed on a plane midway between that of the ear and the mesial plane of the head. For detailed directions as to pose, illumination, &c., see below.

(*b*) The same persons who were taken in side-face should be photographed also in strictly full-face. The focal plane should be that of the front of the cheek.

(*c*) The same persons should be photographed also, if possible, so as to show the top of the head. This, however, is only of value if the subject is bald or shaven, or has very close-cropped hair.

It will add much to the value of the portraits if the same persons have also been measured.

C. Full-length Portraits.

At least twelve adults of each sex should also be photographed at full length, standing, with heels together and arms by the sides. They should be as nearly nude as circumstances permit, and each should be photographed in three positions :—

(*a*) Full-face, with the right arm hanging loosely by the side and the left held across the body between the breasts and the navel, with the fingers extended.
(*b*) Profile with arms hanging loosely by the side.
(*c*) Back view, with arms in the same position as in (*b*).

Of these the full-face view is the most important, and the back view the least important.
For general directions as to pose, &c., see below.

General Directions.

Camera and Lens.—In all cases record should be kept of the focal distance of the lens and of the distance of the sitter from the camera.

A lens of short focus should be avoided. The ordinary field camera is usually fitted with a lens of about 8 inches focal length, but for cabinet portraits nothing under 15 inches is satisfactory, and professional photographers often use lenses of considerably longer focus. Valuable results may even be obtained with a telephotographic lens such as is employed in geographical work.

Rapidity of lens and plates is an advantage : uncivilised folk are impatient subjects. But note that very rapid plates are often too delicate for field-work.

The focussing screen must be kept vertical, and the swing-back should on no account be used in focussing. Otherwise distortion of the image is inevitable.

Size and Scale.—The portraits should be on such a scale that the distance between the top of the head and the bottom of the chin shall in no case be less than $1\frac{1}{4}$ inch (30 mm.). Smaller portraits are of comparatively little value.

For composite work greater uniformity of scale is required. The best results are obtained when the distances between eyes and lips are taken as the constant dimensions.

In every series it is more important that the portraits should be of uniform scale among themselves than that they should be precisely of any standard scale, but the following hints will aid in securing the latter result also :—

Full-length Portraits.

A full-grown man can be photographed easily at full length on a 'half-plate' ($8\frac{1}{2}'' \times 6\frac{1}{2}''$) on the scale of $\frac{1}{10}$, and on a 'quarter-plate' ($4\frac{1}{4}'' \times 3\frac{1}{4}''$) on the scale of $\frac{1}{20}$. But 'half-plate' and 'quarter-plate' are both just too small to admit head-and-shoulders portraits on the scale of $\frac{1}{2}$ and $\frac{1}{4}$ respectively.

Note, however, that the École d'Anthropologie de Paris has adopted the scale of $\frac{16}{200}$ ($=\frac{8}{100}=\frac{1}{12\frac{1}{2}}$) for full-length work, the object being to secure

full-length portraits on the French '13 × 18 cm.' plate (approximately the English 5″ × 7″ size). See *Rev. Ec. Anthr.* viii. (1898), p. 109.

HEAD-AND-SHOULDERS PORTRAITS.

The 'half-plate' and 'quarter-plate' are just too small to admit with security a head-and-shoulders portrait on the scale of $\frac{1}{2}$ and $\frac{1}{4}$ respectively.

The French scale for these portraits, and for other parts of the body in detail, is $\frac{16}{40}$ $(=\frac{4}{10}=\frac{2}{5})$, which permits a head-and-shoulders portrait to be taken easily on a '13 × 18 cm.' plate, and with ample margin on a 'half-plate.' Similarly on the scale of $\frac{1}{5}$ a 'head-and-shoulders' portrait can be taken easily on a 'quarter-plate.'

A board, on which is marked very legibly a scale of feet and inches and also a 'metric' scale, should be suspended over the head of the subject in the plane of his profile, and so as just to fall within the photographic picture. This is the only certain method of preserving a record of the scale, and also makes it easy to secure whatever scale of reduction may be adopted, by comparison of the image of this board with a line or rectangle of proportional size drawn on the focussing screen of the camera.

The name of the district and of the sitter (or at all events a distinctive letter or number) may be written with chalk or charcoal on this same board, thus securing the identification of each subject.

Background.—The background should be at a considerable distance from the subject. It should be of a medium tint (say a deep shadow, or a sheet of light brown or French grey paper pinned against the wall beyond), very dark and very light tints being both unsuitable. Some, however, use dead black; others, red baize. A soft material which does not readily crease obviates trouble from accidental shadows. In any case due allowance must be made for the complexion or skin colour of the persons to be photographed; and preliminary experiment is advisable. A note should be made of the colour of the background, and also of the complexion or skin colour of the subject.

The essential condition is that the outlines of the figure shall be clearly defined against the background.

Illumination.—The incidence of the light should be the same in all cases, otherwise the photographs are difficult to compare, and cannot be used to make composite portraits.

The source of light should be single, definite, and placed behind the camera and above it, so that the shadows may be equally distributed on either side of the face. This is especially important for composite work.

The light, however, must not be so strong or concentrated as to distress the subject or cause him to close or strain his eyes. But note that subdued light involves longer exposure. A dark background behind the camera relieves eye-strain, without cutting off top-light. When the top-light is strong, a white sheet on the ground lightens the shadows, and helps to prevent the subject from looking down.

Mounting.—The photographs should be *mounted on cards*, each card bearing the name of the district, and a letter or number to distinguish the individual portraits; the cards of each series may be secured together by a thread passing loosely through a hole in their upper left-hand corners.

For convenience of comparison and interchange, attention is called to

the standard sizes of mounts adopted by the British Association's Committee on Anthropological Photographs. The ordinary 'cabinet-mount' is used for all sizes up to and including 'half-plate.'

The risk of fading is minimised by avoiding gum or paste; each print being secured by its corners to slits cut in the mount, as in a post-card album. But the only complete security is the use of a really 'permanent' process such as Platinotype.

Detailed Directions as to Pose.

For purposes of comparison, uniformity of pose is essential in photographs in classes *B* and *C* (see above).

For *side-face* (B^a) and for *full face* (B^b) the head should be posed so that a line drawn from the inferior orbital margin to the tragus of the auricle is horizontal. This is a test which can be directly applied in either pose with the help of sights and a level on the side of the camera; for the axis of the camera should lie in the same horizontal plane with the line from the inferior margin of the orbit to the tragus.

Without such provision for uniformity, differences of face projection and prognathism are liable to be obscured or misrepresented.

The subject should look at some object on a level with his eye and at a moderate distance from it.

For *top view of the head* (B^c) the following methods are practicable:—

1. Set the camera on a high stand, pointing vertically downwards, and make the subject sit on the ground below it, with his head posed as for side view.

2. Set the camera to point horizontally, and make the subject lie on his back on a table of suitable height, with his head towards the camera. The line from the inferior margin of the orbit to the tragus should now be vertical.

3. Set the camera to point horizontally; set a chair with its back to the camera; make the subject sit straddlewise on the chair, facing the camera; let him fold his arms on the back of the chair, and bend forward, resting his head on his arms, and looking downwards, till the head is in the right pose; when a plumb-rule will test the line from the inferior margin of the orbit to the tragus.

Suggestions for Rapidity and Uniformity.

By attending to the following hints successive sitters may be made to occupy so nearly the same position that the camera need hardly be refocussed:—

1. Much time will be saved if all the side-faces are taken first, and then all the full-faces; the latter should occupy a different chair, in which case the position of the camera would require to be changed after completing the first series of photographs; unless, indeed, there happen to be two operators, each with his own camera, ready to take the same persons in turn.

2. If the camera has a stand with vertical rack-and-pinion adjustment, the subject's place should be fixed, and the camera should be raised and lowered to suit each subject. A square of the standard size of the picture should be ruled on the focussing screen of the camera.

3. For field work, and wherever the camera has no such adjustable stand, the camera should be set at a fixed height and all the subjects

should occupy in turn the same chair, with movable blocks of known thicknesses on the seat to raise the heads of successive sitters to a uniform height. It is, however, tedious and clumsy to adjust each sitter's height by trial in front of the camera. The simpler plan is to make the sitter first take his place on a separate seat with his back to a wall, on which are previously marked, at heights corresponding to those of the various heights of head, the numbers of the blocks that should be used in each case The appropriate number for the sitter is found and noted, and then the proper blocks are placed on the chair by the observer or an assistant, with the assurance that what is wanted has been correctly done.

4. The position of the sitter is easily controlled by the operator if he looks at the sitter's head over the middle line of the camera, against a mark on the background.

The subject can also be caused to adjust himself approximately by means of sights arranged on the side of the camera, as follows :—

A is a small mirror with a cross + painted on it. It is set at an angle of 45° to the sitter's line of sight.

DIAGRAM A.

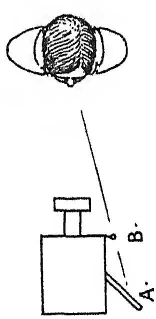
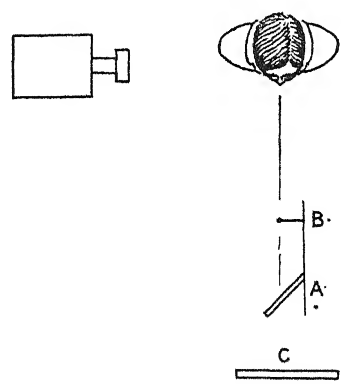


DIAGRAM B.



B is a pin with head of glass or polished metal. The sitter is told to keep the head of the pin sighted in the intersection of the cross.

The same device may be employed in photographing side-face to keep the sitter in the right focal plane. In this case the sights are set up in the focal plane, facing the sitter. Or a small plain mirror (*C*) may be hung up, so that the sitter can only see his face in it when he is in the right pose and focal plane.

Report of the Educational Sub-Committee.

In dealing with anthropometrics in schools the chief factors which the Sub-Committee has had to take into consideration are time, expense, and the object of the investigations. If time and expense did not enter into the question, it is hardly necessary to remark that, from the scientific point of view at least, the measurement of school-children would require no special scheme of observations as apart from a general survey of the population. In present circumstances, however, when a crowded

curriculum reduces the time available for anything outside the absolutely essential to a minimum, and the cost of the education of the large majority of the children is borne by public funds, it is necessary to confine the investigation, so far as possible, to a practical issue more or less immediate.

From an educational point of view the value of an anthropometric survey must lie chiefly in the fact that it affords an accurate indication of the development of the individual, and at the same time provides those responsible for education with some means of judging how far the individual, or individuals, of a particular area are modified, physically and mentally, by the education provided.

The Sub-Committee is therefore of the opinion that the aim of anthropometric observations in schools should be :—

1. To determine norms or averages, standard deviations and correlations at different ages, having due regard to sexual, racial, and environmental differences.

2. To correlate physical and mental growth with a view to testing the efficiency of different systems of education and indicating the amount of work that may advantageously be attempted at different ages, thereby minimising the dangers of over-pressure.

3. To mark out the physically or mentally unfit for special educational treatment. Where the deviation is abnormal in a number of individuals, a whole school, or a whole area, it would point to the necessity for special investigations of social conditions and environment.

4. To correlate physical, mental, and environmental characters with a view to providing a scientific basis for the better adaptation of education to local needs and character.

As regards the anatomical measurements, the Sub-Committee recommends the adoption of the schedules suggested for use in schools by the Anatomical Sub-Committee (see p. 357).

The adoption of a particular schedule must depend largely on local circumstances and finance. And although it must be remembered that more accurate conclusions are to be obtained from a few measurements of a large number of individuals than from a large number of observations on a few individuals, the value of a survey would be increased in proportion as a schedule containing a larger number of observations were generally adopted. The Sub-Committee is of the opinion that the teachers, with a little practical instruction, would be capable of making and recording the necessary measurements. In addition to actual measurements, careful note should be taken of the general physical condition, and a record of average (not record) performances in athletic sports and of proficiency in games should be kept.

In the case of the psychological observations the conditions are somewhat different. They would necessarily extend over a more or less lengthy period, and therefore should, if possible, be entrusted to the teacher. Graduated schedules for use in schools have not yet been drawn up, but the teachers—who, it must be remembered, at any rate in the elementary schools, have received some training in the observation of the psychical characters of childhood—may select for themselves from the schedule tentatively suggested by the Psychological Sub-Committee (see p. 360) the characters with which they feel themselves most competent to deal.

With regard to the record of observations, unless a special inquiry is

necessitated by local circumstances, some uniform system should be adopted, and the method of envelopes and cards suggested in the previous year's Report, which includes a record of family history, seems most desirable.

To secure the full value of the records a central body should be established upon which should devolve the comparison and statistical treatment of the observations made. Its duties should include the determination of average values, standard deviations, and correlations in different conditions; and when this has been done, the reporting the results of an examination of the material submitted to it to local education authorities and others interested.

The Physiological Sub-Committee has not reported, but, in the event of the Anthropometric Committee being reappointed, it is proposed that this Sub-Committee should prepare a code of instructions for testing vision, hearing, tactile sensibility, &c. &c., for the Report of next year.

It is further considered desirable that the Committee should report upon the factors of the environment which it would be advantageous to observe and record.

Much useful work still remains to be done. The Committee therefore request that they should be reappointed, that the unexpended balance of the grant (13*l.* 9*s.* 1*d.*) should be carried over to next year, and that an additional grant of 10*l.* be voted for the furtherance of the work of the Committee.

The Age of Stone Circles.—Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Mr. H. BALFOUR (*Secretary*), Sir JOHN EVANS, Dr. J. G. GARSON, Mr. A. J. EVANS, Dr. R. MUNRO, Professor BOYD DAWKINS, *and* Mr. A. L. LEWIS, *appointed to conduct Explorations with the object of ascertaining the Age of Stone Circles.* (*Drawn up by the Secretary.*)

THE Committee report that with a view to the execution of the work for which a small grant was made at the last meeting of the Association, they asked Mr. H. St. G. Gray to make detailed surveys and plans of the Fernacre and Stannon Stone Circles on Bodmin Moors, Cornwall. This work has been satisfactorily and skilfully done, and the surveys of the group of five circles in this neighbourhood are now complete, the other three circles, viz., the 'Stripple Stones,' the 'Trippet Stones,' and Leaze Circle having previously been made. The measurements at the Fernacre and Stannon circles occupied Mr. Gray from September 18 to September 25, 1906, and from them two large-scale plans in 6-inch contours have since been prepared. Detailed notes, sketches, and photographs were also made, and a valuable record of these circles has thus been secured. The 'Trippet Stones' and Leaze Circle were revisited for the purpose of checking some measurements. It is satisfactory to be able to state that nearly all traces of the excavation work conducted in 1905 at the 'Stripple Stones' have now disappeared, the grass having grown again excellently over the disturbed places.

Mr. Gray's detailed report upon the work done is appended. It may be added that the thanks of the Committee are due to Mr. Gray, who undertook the work without any remuneration. The Committee ask to be reappointed, with the addition of Lord Avebury to their number. Lord Avebury has very kindly agreed to excavations being made at Ave bury Stone Circle, and it is greatly to be hoped that a grant may be made for this purpose. The Avebury circle is perhaps the most important in Great Britain, and it is most desirable that this site should be excavated with a view to gaining fresh evidence as to the period to which the circles belong. Owing to there being a very fine fosse connected with this monument, it is likely that far more definite results may be obtained upon this site than upon any other. The careful exploration of this circle is one of the most important pieces of archæological work remaining to be done in Great Britain. To make detailed partial excavations on the site will involve an expenditure of some 120*l.* at least, and the Committee ask for a grant of this amount.

Notes on the Survey of the Fernacre and Stannon Stone Circles, East Cornwall, 1906. *By* H. St. George Gray.

I. *The Fernacre Stone Circle.*

1. *The Position of the Circle.*—Fernacre Circle, which belongs to Sir William Onslow, Bart., is in the parish of St. Breward, the village of which is 3⅝ miles distant in a S.W. direction,[1] and the same distance to the S.E. of Camelford. It is about 925 feet above the mean level of the sea. Hut-circles abound to the E. between the circle and Fernacre farm, and to the N. on the southern slopes of Rough Tor. To the S. and W.S.W. are barrows and stone cists. To the N.W. at a distance of 4¼ furlongs, is the Logan Rock at the N. extremity of Louden Hill. The view from the circle is confined to a comparatively small area, bounded on the N. by Rough Tor, on the S. by Garrow Tor, on the E. by Brown Willy, and on the W. by Louden Hill.

The Fernacre Circle is situated at the following distances from the neighbouring circles: The Stripple Stones, 15,675 feet (three miles), due S.; the Trippet Stones, 16,810 feet (3¼ miles), S.S.W.; the Leaze Circle 9,220 feet (1¾ mile), S.S.W.; the Stannon Circle, 6,270 feet (9½ furlongs), W. The Stripple Stones, the Leaze, and Stannon Circles are almost in line, and the same remark applies to the Trippet Stones, the Leaze, and Fernacre Circles. By reference to the 6-inch Ordnance sheets it is seen that the summit of Brown Willy, Fernacre, and Stannon Circles are *very* nearly in the same alignment, but the line connecting the former and the latter misses being due E. and W. by just 2°, Fernacre falling a little S. of this line; Brown Willy is the most northerly of the three.

2. *Description of the Circle.*—The plan encloses an area 175 feet due N. and S. by 175 feet E. and W., the ground covering 0·7 acre. The magnetic variation for September 1, 1906, at Brown Willy was 17° 18′ W. of true N. The plan with its 6-inch contours shows a maximum fall of 12½ feet from the highest ground in the N.E. corner to the lowest at the S.W.

Details regarding the position and size of the stones have been carefully recorded. A mere glance at the plan shows that the stones were

[1] All measurements are taken as the crow flies.

probably never placed in the form of a true circle, unless 'soil-creep' is responsible for more than I should be inclined to credit it with; still it must be borne in mind that the ground (peat) is very boggy in wet seasons (even more so than at the other circles). The nearest approximation to a segment of a true circle is on the W. side, where the stones are placed about 7 feet apart. Out of the seventy-one stones [1] shown in my plan thirty-nine are standing (including stumps), the remainder being prostrate or partly sunk into the peat, whilst others could only be indicated on the plan after probing and digging.

All the stones are of granite. The highest standing stone is No. VI, which leans slightly and is surrounded by a depression about 1 foot deep; its height above the level of the moor is 4·4 feet. Stone XIV comes next with a height of 3·7 feet, while Stone XXXII is 3·4 feet high. Of the prostrate stones No. LXIV is by far the longest, length 6·9 feet; and No. XIV is by far the widest stone—width 4·2 feet. Nos. XXXII, XXXIV, and LXVI are also comparatively large stones. Early prostration of several of the standing stones is to be feared, both here and at the Stannon Circle, as many of them lean considerably, and some are deeply trenched round by the feet of cattle.

A mediate circle has been delineated on the plan, which gives an approximate diameter of 149 feet for the ring. Mr. G. F. Tregelles records the diameter as about 146 feet, but the circle described on his plan shows the ring to be of the same diameter as that on my plan.

3. *Outlying Stone.*—Both Mr. A. L. Lewis and Mr. Tregelles have stated that an outlying stone is situated about 160 feet eastward from the circle directly in line with the highest peak of Brown Willy. Now these observations should be taken from the centre of the circle, and I find that the outlying stone is about $1\frac{1}{2}°$ to the N. of a line drawn from the circle's centre to the highest point of Brown Willy.[2] This small stone is 231 feet from the centre of the circle, and $154\frac{1}{2}$ feet from the middle of the eastern stone No. XIV.

II. *The Stannon Stone Circle.*

1. *The Position of the Circle.*—Stannon Circle is the most north-westerly of the group of five circles on Bodmin Moors, and is in the parish of St. Breward. Like the Stripple Stones and the Fernacre Circle it is the property of Sir William Onslow, Bart. This circle is only $1\frac{3}{4}$ furlong to the S.S.W. of Stannon Farm, and $2\frac{1}{2}$ miles to the N.E. of St. Breward; from Camelford it is $2\frac{1}{2}$ miles in a bee line in a S.E. direction. To the S.S.W. of the circle there is a tumulus on Dinnever Hill, and hut-circles abound on the E.N.E., E., and E.S.E. Alex Tor is situated $7\frac{1}{4}$ furlongs to the S.W., and Rough Tor towers over the N. extremity of Louden Hill at a distance of $12\frac{1}{2}$ furlongs in an E.N.E. direction. On the E. the peaks of Brown Willy, over the S. slope of Louden Hill, stand out conspicuously against the sky-line. The circle is about 835 feet above mean sea-level. A small tributary of the River Camel rises a little to the east of the circle.

[1] Mr. Lukis in 1879 said that the circle consisted of ten fallen and forty-five erect stones. He stated also that the diameter of the circle was 140 feet, but his plan shows it to be about 147 feet.

[2] The summit of Brown Willy is about $2\frac{3}{4}°$ N. of E., viewed from the centre of the Fernacre Circle.

The Stannon Circle is situated at the following distances from the neighbouring circles : The Stripple Stones, 16,770 feet (about $3\frac{1}{4}$ miles), S.E. ; the Trippet Stones, 16,350 feet (over 3 miles), S.S.E. ; the Leaze Circle, 9,530 feet (about $1\frac{3}{4}$ mile), S.E. ; the Fernacre Circle, 6,270 feet ($9\frac{1}{2}$ furlongs), E. A line connecting Stannon Circle with the summit of Brown Willy is only 2° N. of E., and the Fernacre Circle falls only 100 feet to the S. of this line.

2. *Description of the Circle.*—The plan encloses an area 165 feet due N. and S. by 157 feet E. and W., the ground covering about 0·6 acre. The contours of 6 inches vertical height show a gradual fall of $8\frac{1}{2}$ feet from the highest ground in the S.E. corner to the lowest at the N.W. The surveying was greatly impeded by the luxurious growth of gorse in most parts of the circle.[1] Much had to be cut away for our purposes, and there was considerable difficulty in revealing the true outline of many of the prostrate stones, and in some cases, either on account of the abundance of gorse or from the fact that some of the stones were entirely clothed in turf, only the approximate outline of the granite blocks could be delineated on the plan.

Details of the dimensions and position of the stones have been carefully recorded. As in the case of the Fernacre Circle, the stones at Stannon could never have been placed in the form of a true circle. Indeed the Stannon stones deviate much more from a true circle than those at Fernacre. The nearest approximation to a segment of a circle in the case of Stannon is on the S., S.E., and E. By far the greatest amount of flattening of the circle occurs on the N., while at the N.W. there is almost an angle formed by the position of the stones.

The N.W. quarter of the circle shows the best line of stones still erect, and had not Stones LXXI and LXXII fallen outwards there would have been twelve stones standing in sequence in their original position, apparently without any deficiencies between.

Of the seventy-nine stones shown in the circle and within it in my plan, forty-one are standing (including stumps), the remainder being prostrate or partly sunk into the peat, whilst others could only be indicated on the plan after probing, digging, or gorse-cutting.

The highest standing-stones are close together on the S.W. ; Nos. LVI and LIX are each 3·55 feet above the field level, and No. LII is 3·1 feet in height. Stone LXIV leans outwards considerably, but when erect its height was probably 3·8 feet. Of the prostrate stones Nos. XXXVIII and IX are the longest, the lengths being 5·8 and 5·5 feet respectively. These are closely followed by Nos. XIII, VII, and V, with lengths of 5·35, 5·3, and 5·2 feet respectively. The widest stone in the circle is No. LXIV, width 4·5 feet ; this is closely followed by Nos. LII and IX, 4·4 and 4 feet wide respectively.

A circle has been described on the plan which, although including the somewhat flattened portion on the N. well within its area, is mediate for the stones on the E., S., and W. It gives a diameter of 138 feet.

3. *Outlying Stone.*—At 30° E. of N., as observed from the centre of the circle, there is an outlying stone (No. LXXX of plan) at a distance of 25 feet from the nearest part of the circle described on the plan, and 94 feet from the centre of the circle. This standing-stone probably belongs to this group of stones. It leans in a N.E. direction towards

[1] See photographs.

Rough Tor at an angle of about 50° with the ground. When erect it was about 1·8 foot above the turf. Its maximum basal width is 4·6 feet, so that it is wider than any of the other stones comprising the Stannon group.

III. *General Remarks.*

From the fact that neither the Fernacre nor the Stannon Circle are true circles,[1] it has been contended that they may be earlier in date than the circles in the southern division of the group, viz., the Stripple and Trippet Stones and the Leaze Circle. Such an assumption can only be proved by excavations. I am not aware that any remains of human workmanship have been found in any of these circles, except the few flint flakes and a calcined flint in the excavations conducted at the Stripple Stones in 1905. As the Fernacre and Stannon circles are in close proximity to the sites of dozens of hut-circles, it is probable that the two classes of ancient sites are contemporaneous in date, and that the inhabitants of the huts used the circles for various ceremonies and observances. These circles might repay excavating if done carefully, but stone circles in England, with the exception of Stonehenge and Arbor Low, have produced little in the way of relics.

In cart-tracks and along a little runnel of water just below the hut-circles on the southern slope of Rough Tor, and between it and the Fernacre Circle, Mrs. Gray found within half an hour six flint chips, a small scraper, two cores, a flake with secondary chipping, and a flint knife, nearly 2 inches long, with traces of considerable chipping.

The stones in the five circles are of granite. Those forming the Stripple and Trippet Stones and the Leaze Circle are for the most part solid and well cut, with quadrangular cross-section. The stones making up the Fernacre and Stannon Circles are, on the other hand, smaller as a whole,[2] and with few exceptions are rough and irregular in outline. The three southern circles, and especially the Trippet Stones and the Leaze Circle, have the megaliths placed at fairly regular intervals apart. The Stripple Stones appear to have been arranged about $16\frac{1}{2}$ feet apart; the Trippet Stones have intervals of $12\frac{3}{4}$ feet dividing the stones; and the spaces between the stones of the Leaze Circle average 12 feet. The Fernacre and Stannon Circles, on the other hand, present uneven outlines, and the remaining stones in some places occur in close order, in others at irregular intervals. Instances of similar circles are recorded. Withypool, which I have surveyed, is a recent discovery of the sort.[3] Mr. C. W. Dymond has figured Cumbrian circles of this character;[4] they include Long Meg and her Daughters, the Keswick, Swinside,[5] and Eskdale Circles. The former of these (average diameter 332 feet) has a similar flattening on the N. side to that of the Stannon Circle The comparatively small circle of Boscawen-ûn, in the parish of Buryan, near Penzance, is elliptical in shape; in this case the stones follow the line of a true circle on the N.E. and S.W., but in the other parts they bulge out.

[1] How easily these rings could have been made true circles by means of a central pole and a cord for radius.

[2] The stones of the Stannon Circle are rather larger and more uniform than those of Fernacre.

[3] *Proc. Som. Arch. and N. H. Soc.*, LII., pt. ii., 42–50, and plan.

[4] *Journ. Brit. Arch. Assoc.*, vol. xxxiv., 31–6.

[5] *Trans. Cumb. and West. Antiq. Soc.*, N.S., ii. p. 55 *et seq.*

Both Fernacre and Stannon Circles have an outlying stone near to; the former on the E., the latter on the N.N.E. The former, as viewed from the centre of the circle, does not form an exact alignment with the summit of Brown Willy, and the use of the latter has not been ascertained.

Another point to be noticed in this group of circles is that none of the circles can be seen from the others, with the exception of the Trippet Stones, which, viewed from the Stripple Stones, stands out grandly along the sky-line; but the Stripple Stones are not well seen from the Trippets.

All the circles are highly placed above sea-level. The Trippet Stones are the lowest, about 799 feet, whilst the Fernacre Circle is the highest, about 925 feet above mean sea-level. The Leaze Circle, about 815 feet; Stannon Circle, about 835 feet; and the Stripple Stones, about 915 feet.

In diameter, Fernacre is the largest circle in Cornwall; allowing for irregularities, it averages 149 feet. The Stripple Stones come next with a diameter of $146\frac{1}{2}$ feet. Of the others in the group, the diameters are as follows: Stannon, 138 feet; Trippet Stones, 108 feet; and the Leaze Circle, 81 feet. These have been estimated with every attention to accuracy. Mr. Tregelles gives the diameters as 146, 145, 138, 103, and 80 feet respectively.

Exploration of the 'Red Hills' of the East Coast Salt Marshes.—Report of the Committee, consisting of Professor R. MELDOLA *(Chairman)*, Mr. F. W. RUDLER *(Secretary)*, Mr. C. H. READ, *and* Mr. T. V. HOLMES. *(Drawn up by the Secretary.)*

As the Committee were appointed without any grant, they have not been able to undertake any active work in the field. It happened, however, that all the members of this Committee were also members of the 'Red Hills Exploration Committee,' which, at the suggestion of Mr. I. Chalkley Gould, had been appointed jointly by the Essex Archæological Society and the Essex Field Club. This Committee carried out last autumn some important investigations in certain 'red hills' in the parish of Langenhoe, in N.E. Essex, where permission to dig had been obtained by Dr. H. Laver of Colchester, who acted as director of the excavations. Three mounds were systematically examined, under the careful superintendence of Mr. Francis W. Reader, whilst a cursory examination was made of several neighbouring hills. These mounds yielded numerous fragments of the coarse red pottery so common in the 'Red Hills,' with a few of the characteristic objects of red ware known as wedges and T-pieces, such as were exhibited at the last meeting of the British Association. Fragments of a finer dark-coloured pottery were also found, and one mound yielded a portion of a large bowl believed to be of Late Celtic age. The other objects exhumed included fragments of hard vitrified slag and animal bones, with antlers of the red deer. The site of all the 'red hills' in the districts of Langenhoe, Wigborough, and Mersea have been accurately laid down by Mr. W. H. Dalton on the 6-inch maps kindly supplied by the Director of the Ordnance Survey.

The Joint-Committee have issued an interim report, in which they express the opinion that the work is not yet sufficiently advanced to justify any definite conclusion as to the origin and uses of the 'red hills.' Further exploration is therefore to be undertaken, and in order to assist in this work your Committee ask to be reappointed, with a grant of 10*l*.

Anthropological Photographs.—Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Mr. H. S. KINGSFORD (*Secretary*), Dr. T. ASHBY, Dr. G. A. AUDEN, Mr. H. BALFOUR, Mr. E. N. FALLAIZE, Dr. A. C. HADDON, Mr. E. SIDNEY HARTLAND, Mr. E. HEAWOOD, Mr. J. L. MYRES, *and* Professor FLINDERS PETRIE, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.* (*Drawn up by the Secretary.*)

THE Committee issue with this report the second list of photographs registered with them.

An important matter has come to the front during the past year—namely, the position which already existing collections of photographs should bear to the register of the Committee. For example, most of the missionary societies have large and valuable collections of anthropological photographs which they are willing should be registered, but of which copies cannot be obtained for the Committee's collection. As it would be unfortunate if these collections were not made available for students, the Committee feel that some modification of the conditions under which photographs are accepted for registration is needed, and that the primary object of their work should be the registration rather than the collection of photographs. The Committee therefore propose that where duplicate copies cannot be obtained, except at considerable expense, a collection should be registered and, where possible, a detailed catalogue published, giving a reference to the place where the collection may be seen. The Committee do not propose to give up collecting photographs, but in special cases they will be willing to register photographs without making the presentation of copies a condition of doing so.

The system of numbering and arrangement was published in the last report of the Committee. The following is a list of the numbers already allocated:—

1–2000.	The Royal Anthropological Institute, 3 Hanover Square, W.
2001–3000.	Mr. J. L. Myres, Christ Church, Oxford.
3001–4000.	Dr. D. Randall-MacIver, Wolverton House, Clifton, and the late Mr. Anthony Wilkin.
4001–5000.	Mr. T. V. Hodgson, 54 Kingsley Road, Plymouth.
5001–6000.	Professor C. S. Myers, Galewood Tower, Great Shelford, Cambridge.
6001–7000.	Mr. J. L. Myres, Christ Church, Oxford.
7001–8000.	Mr. Edgar Thurston, Government Museum, Madras.
8001–9000.	Will be used for small series or single photographs.
(8002–8015.	Miss E. M. Hartland, Highgarth, Gloucester.)
9001–10000.	Dr. W. H. R. Rivers, St. John's College, Cambridge.
10001–11000.	Dr. C. G. Seligmann, 15 York Terrace, N.W.
11001–12000.	Dr. G. A. Auden and Dr. H. A. Auden, Bootham, York.
12001–13000.	Dr. A. C. Haddon, F.R.S., Inisfail, Hills Road, Cambridge.

The Committee ask to be reappointed, retaining the balance in hand.

SECOND LIST OF PHOTOGRAPHS.

EUROPE.

DENMARK.—*Photographed by* Dr. G. A. AUDEN, *Bootham, York.*

11014. Jellinge, model of the Gorm Stone, with Runic inscription.

FRANCE.

Collection, Royal Anthropological Institute.

Abbeville.

218, 219. Human jaw.

Basque.

268. Young man with bullock cart.

Brittany.

501. Breton man and woman.

Photographed by Dr. G. A. AUDEN, *Bootham, York.*

11056. Polished stone celts.
11066. Carnac, Dolmen la Trinité.
11068. Carnac, Cromlech (Circle) Menec.
11069–70. Carnac, alignments of Menec.
11071. Carnac, alignments of Kermario.
11058. Huelgoat, Koat Mocun monolith.
11059. Huelgoat, Kerampeulven monolith.
11061. Locmariaker, table des marchants (dolmen) cromlech.
11062. Locmariaker table des marchants (dolmen) cromlech, interior.
11063. Locmariaker, dolmen Kerveres.
11064. Locmariaker, dolmen Kerock.
11065. Locmariaker, dolmen Le Mané Rétual.
11067. Locmariaker, Men-er-H-roeck (fallen monolith).

NORWAY.

Collection, Royal Anthropological Institute.

502. Lapp family.

POLAND.

Collection, Royal Anthropological Institute.

237, 238. Young adult male.

RUSSIA.

Collection, Royal Anthropological Institute.

651–688. Series of ethnographical types.

UNITED KINGDOM.

ENGLAND.

Photographed by Dr. G. A. AUDEN.

Cheshire.

11019. Pre-Norman crosshead and portion of shaft, Cheadle (York Museum).

Collection, Royal Anthropological Institute.

Cornwall.

278. Six photographs of selected types.

Photographed by Dr. H. A. Auden.

11503. Bolleit, part of stone circle.
11512. Boscawen Point, St. Buryan, monolith.
11504. Bosporthennis, beehive hut.
11522. Chywoon, cromlech.
11511. Land's End, Ruins on Carn Brea.
11505. Lanyon, cromlech.
11523. Lanyon, West cromlech.
11524. Madron, Men-an-Tol (holed stone).
11542. Madron, 'Rialobran' inscribed stone.
11502. Newlyn, 'Faugau Stones.'
11508. Paul, Chy-an-Hal monolith.
11527. Penzance, Chysauster, 'British Village.'
11528. Penzance, Chysauster, details of portion of hut.
11506, 11526. Rosemoddress, holed stone.
11507, 11540. Rosemoddress, 'The Pipers.'
11514. Rosemoddress, Goon-rith monolith
11541. Rosemoddress, 'Borah Circle,' now partially destroyed.
11509. Sancreed, Brane, beehive hut, exterior.
11513. Sancreed, Tremethick cross.
11515. Sancreed, 'Blind Fiddler' monolith.
11516. Sancreed, 'Brother and Sister' monoliths.
11517. Sancreed, Boscawen-un monolith.
11518. Sancreed, Trelew monolith.
11519. Sancreed, Tresvenek monolith.
11520. Sancreed, Pridden monolith.
11512. St. Buryan, Boscawen Point, monolith.
11510. St. Cleer, Trevethy, cromlech.
11521. St. Just, Boskednan, circle.
11525. St. Just, Carnyorth, holed stone.

Collection, Royal Anthropological Institute.

Gloucestershire.

220. Beller's (Bellas) Napp Barrow, human jaws.
221. Beller's (Bellas) Napp Barrow, skull.

Photographed by Dr. G. A. Auden.

Monmouthshire.

11048. Caerwent, South Gate.
11049. Caerwent, part of wall and tower.
11047. Staunton, font (? originally Roman altar).
11050. Staunton, monolith.
11051. Trellech, alignment, three standing stones.

Photographed by Dr. H. A. Auden.

Staffordshire.

11054. Rollestone, pre-Norman cross from Tatenhill.

Photographed by Dr. G. A. Auden.

Westmorland.

11004–9. Bowl found in Ormside Churchyard (York Museum).

Yorkshire.

11032. Arras, Market Weighton, stellate fibula and pendant inlaid with coral, chariot burial (York Museum).
11033. Hesselskew, Market Weighton, part of jet necklace, chariot burial (York Museum).

11030. Driffield, Two cruciform bronze fibulæ (York Museum).
11031. Driffield, five bronze fibulæ (York Museum).
11024. Folkton, near Filey, pre-Norman cross-shaft (York Museum).
11034. Kilham, three bronze fibulæ (York Museum).
11029. Londesborough, bronze fibula and buckle (York Museum).
11040. Boroughbridge, Devil's Arrows alignments.
11012. Skipwith, flint axe-head with polished edge.
11041. Skipwith, inscribed stone, (?) Scandinavian.
11013. Skipwith, tracing of (?) Scandinavian carving (11041).
11042. Stillingfleet, ironwork on church door (Viking ship, &c.) ('Reliq.,' Apr. 1907).
11053. Stonegrave, pre-Norman cross.
11057. Whitby, cup and ring markings.
11027–28. Thorpe, near Bridlington, Late Celtic sword with enamelled handle (York Museum) (see 'Reliquary,' October 1906).
11001–3. York Museum, late Celtic bowl with zoömorphic handles ('Reliq.,' Jan. 1906).
11004–9. York Museum, the Ormside bowl ('Reliq.,' July 1907).
11011. York, The Retreat, earthenware bowl, primary interment of Lamel Hill tumulus.
11015–16. York, portion of pre-Norman cross-shaft.
11017. York, St. Mary Bishophill, pre-Norman grave-slab.
11018. York, portion of pre-Norman hog-backed grave-slab.
11019. York Museum, pre-Norman cross-head, &c., from Cheadle, Cheshire.
11020. York Museum, pre-Norman grave-slab of Scandinavian design.
11021. York Museum, pre-Norman carved slab.
11022–23. York Museum, pre-Norman coped gravestone.
11024. York Museum, pre-Norman cross shaft from near Filey.
11027–28. York Museum, late Celtic sword from Thorpe.
11029. York Museum, bronze fibula and buckle from Londesborough.
11030. York Museum, two cruciform bronze fibulæ from Driffield.
11031. York Museum, five bronze fibulæ from Driffield.
11032. York Museum, stellate fibula and coral inlaid pendant from Arras.
11033. York Museum, part of jet necklace from Hesselskew.
11034. York Museum, three bronze fibulæ from Kilham.
11035. York Museum, Scandinavian wooden spoons, knife, &c.
11036. York Museum, Scandinavian stone weight.
11043. York Museum, carved bone of Viking age.
11044. York Museum, fragment of pre-Norman altar from St. Andrews ('Reliq.,' Oct. 1906).
11045. York Museum, bronze votive tablets, coated with silver, with Greek inscription.
11046. York Museum, iron lynch-pin, chariot burial 'Danes' Graves.'
11055. York Museum, bronze fibula from the Wolds.
11037. York Minster Library, earliest known list of Scandinavian personal names, A.D. 1023.
11038–39. York Minster Library, initial letters, Anglo-Saxon MS. of Gospels, A.D. 950.

WALES.

Collection, Royal Anthropological Institute.

279. Six photographs of selected types.

Photographed by Dr. H. A. AUDEN.

Anglesea.

11537. Cromlech, Bodorgan.

Photographed by Dr. G. A. AUDEN.

Brecon.

Ogam stone from Defynnock, now in British Museum.

Cardigan.

11091. Ogam stone, Kilgerran.
11092. Ogam stone, Clydai.

Photographed by Dr. H. A. Auden.

Carnarvon.

11529. Cromlech, Criccieth.
11532. Cromlech, Criccieth.
11530. Cromlech, Duffryn.
11534. Cromlech, Duffryn.
11531. Cromlech, Clynog, No. 1.
11533. Cromlech, Clynog, No. 2.
11535. Cromlech, Llandudno.
11536. Trer Ceiri.

Photographed by Dr. G. A. Auden.

Pembroke.

11084. Carningle, hut circles.
11010. Llanwnda, pre-Norman grave-slab (rubbing).
11072. Monolith, St. Nicholas Moor.
11073. Longhouses, cromlech.
11074. Newport, Llech-y-dribleth, cromlech.
11075. Newport, cromlech.
11076. Pentre-evan, cromlech.
11077. St. David's Head, cromlech.
11083. St. David's Head, hut circles.
11078. Goodwic, cromlech No. 1.
11079. Goodwic, cromlech No. 2.
11080. Goodwic, Carn-gil-fach, cromlech.
11081. Goodwic, Llanwnda cromlech.
11086. Goodwic, Llanwnda, inscribed cross.
11082. Llanawer, near Fishguard, alignment, four stones.
11085. Llanllawer, holy well.
11087. Nevern, St. Brynach Cross.
11088. Nevern, Ogam bilingual stone.
11089. Ogam bilingual stone, St. Dogmael's Priory.
11090. Ogam bilingual stone, Bridell.

ASIA.

Andaman Islands.—Collection, Royal Anthropological Institute.

240, 241. Chief of tribe near Port Blair and wife.
242. Five young women.
243. Women of South Andaman.
244. Group: widow with skull of husband.
245. Wife of chief of Rutland Island.

Borneo.—Collection, Royal Anthropological Institute.

158–173. Ethnographical objects.

Sarawak.

251, 252. Kayan man.
253, 254. Kenyah man.
255–257. Sea Dayak warriors.
258, 259. Sea Dayak girl.

Borneo.—*Photographed by* Dr. C. G. Seligmann, 15 *York Terrace, N.W.*

10001. Baram Bazaar.
10002. Baram Bazaar.
10003. Baram Bazaar.
10004. Baram Kampong.
10005. Baram Kampong.
10006. Baram Kampong.

10007. Baram River, Nipa.
10008. Baram River, outpost on.
10009. Batu Clob.
10010. Blowpipe, piece of wood about to be made into.
10011. Blowpipe, boring.
10012. Blowpipe, boring.
10013. Blowpipe, boring.
10014. Blowpipe, boring.
10015. Blowpipe, instruments used for boring pith dart buts.
10016. Blowpipe, instruments used for boring pith dart buts.
10017. Blowpipe, use of.
10018. Boat race.
10019. Brooketown.
10020. Brooketown.
10021. Brunei.
10022. Brunei.
10023. Brunei.
10024. Brunei.
10025. Brunei.
10026. Camp, Kenyah.
10027. Camp, midday.
10028. Camp, temporary.
10029. Camp, temporary.
10030. Camp, temporary, breaking up.
10031. Camp, Kenyah, temporary.
10032. Camp, Kenyah, temporary.
10033. Camp, Kenyah, temporary.
10034. Canoe.
10035. Canoe.
10036. Canoe, Baram River.
10037. Canoe head.
10038. Canoe figure-head.
10039. Canoe figure-head.
10040. Canoe, Marudi.
10041. Canoe, Marudi.
10042. Canoe, Marudi.
10043. Canoe prow.
10044. Canoe race.
10045. Canoe race.
10046. Canoe race, end of.
10047. Carriers, group of.
10048. Carrying pig.
10049. Carrying pig.
10050. Cave.
10051. Cave.
10052. Cave, near.
10053. Cave, mouth of.
10054. Cave, mouth of.
10055. Cave, entrance to.
10056. Cave, entrance to.
10057. Cave, entrance to.
10058. Cave, interior of.
10059. Chinese merchant boat, Baram River.
10060. Dayak girl.
10061. Dayak man.
10062. Dayak and wife in gala costume.
10063. Dayak man.
10064. Dayak man (see also 10170, 10171).
10065. Dayak and Chinese woman, half-breed.
10066. Dayaks, Land.
10067. Dye plant.
10068. *Euphorbia ligularia*, used for poisoning fish.
10069. Root of species of *Dioscurea*, used for poisoning fish.
10070. Fishing at mouth of Baram River.

10071. Fishing, casting net.
10072. Fishing, casting net.
10073. Fishing trap.
10074. Fishing, tuba.
10075. Fishing, tuba.
10076. Fishing, tuba.
10077. Fishing, tuba.
10078. Fishing, throwing out tuba in basket.
10079. Fishing, weighing tuba.
10080. Fishing, weighing tuba.
10081. Fishing, weir.
10082. Houses on Baram River.
10083. House, Bessiah.
10084. House, corner of, Tugolis.
10085. House, Dayak.
10086. Houses, Dayak (see also 10192, 10193).
10087. House, head, Land Dayak.
10088. House, fireplace in.
10089. House, floating.
10090. House, Kenyah, on river bank.
10091. House, long..
10092. House, long.
10093. House, long.
10094. House, long.
10095. House, long (see also 10194).
10096. House, small.
10097. House, Malay, with woman and child.
10098. Ipoh, in bamboo clump.
10099. Ipoh, cutting tree.
10100. Ipoh, cutting tree.
10101. Ipoh, collecting.
10102. Ipoh, tools used for scoring bark of tree.
10103. Ipoh, cooking.
10104. Ipoh, poisoning darts.
10105. Ipoh, poisoning darts.
10106. Ipoh, making basket for.
10107. Ipoh, packet of poison.
10108. Ipoh, palm-leaf vessel used for inspissating juice.
10109. Ipoh, dish in which Ipoh is mixed into a paste.
10110. Jar burial.
10111. Joss-house, Kuching.
10112. Kayan (see also 10125–10127).
10113. Kenyah funeral arrangements.
10114. Kenyah girl.
10115. Kenyah.
10116. Kenyah woman.
10117. Kenyah woman.
10118. Kenyah woman.
10119. Kuching.
10120. Kuching bazaar.
10121. Kuching bazaar.
10122. Kuching from river.
10123. Kuching, street in.
10124. 'Lada' embroidery.
10125. Ledam (Kayan).
10126. Ledam (Kayan).
10127. Ledam (Kayan).
10128. Lobong Jumong, entrance.
10129. Lumbang, women and children.
10130. Malay boys.
10131. Malay dance.
10132. Malinau, going up rapids.
10133. Marudi village and river.
10134. Natives taking midday meal.

10135. Natives paying taxes.
10136. Natives paying taxes.
10137. Natives fighting.
10138. Native, Orang Kaya of Tumangong.
10139. Native, Orang Kaya of Tumangong, in war dress.
10140. Native, Orang Kaya of Tumangong, in house.
10141. Native man with bark coat.
10142. Native man and woman.
10143. Native lads.
10144. Natives watching races.
10145. Natives going to pay tribute.
10146. Native woman carrying baby.
10147. Native man and woman in corner of house.
10148. Native women.
10149. Nose flute.
10150. Offerings on river bank.
10151. Peace-making hall.
10152. Punan man.
10153. Punan man.
10154. Rangas plant, said to be used in certain arrow poisons.
10155. Rejang.
10156. Rice baskets and blowpipe.
10157. Rice cultivation, field scare.
10158. Rice girls.
10159. Rice houses.
10160. Rice pounding.
10161. Rice winnowing.
10162. Rock sleeping-place near Lobong Juman.
10163. Sago making.
10164. Sago making.
10165. Sago manufactory.
10166. Sarawak, street in.
10167. Sham fight.
10168. Skulls in Long house.
10169. Tatued youths, Punans.
10170. Dayak man and women.
10171. Dayak women.
10172. River bank.
10173. View from fort.
10174. View.
10175. View from hill near cave.
10176. View from fort.
10177. View early morning.
10178. Verandah.
10179. Verandah.
10180. Verandah.
10181. Verandah and house.
10182. Waterfall.
10183. Waterfall in wood.
10185. Grave, mock tomb.
10186. Grave.
10187. Grave, pillar.
10188. Graves.
10189. Graves.
10190. Grave, man's.
10191. Ceremonial hornbill.
10192. House.
10193. House, with large ladder.
10194. Long house.

BORNEO, SARAWAK.—Collection, Royal Anthropological Institute. *Photographed by* Mr. R. SHELFORD, 3 *Wellington Square, Oxford.*

1043. Bakatan girl.
1057. Bakatan man.
1081. Baloi Gorge.
1077. Baloi Dalam River.
1112. Baram River at Claudestown.
1089. Baram River, Kenyah Village.
1091. Baram River, Long Asai.
1059, 1115. Baram River, MacDougall Falls.
1011, 1012. Brunei, views in.
1165. Brunei Gong.
1061. Bukit Batu, Rejang District.
1107. Camp in gravel bed.
1062. Dapoi River.
1116. Dayak warfare.
1073, 1142. Dayaks, Land.
1141. Dayaks, Land, chief.
1142. Dayaks, Land, corsets.
1099. Dayaks, Land, head house.
1055, 1063–1065. Dayak, Sea.
1052, 1116. Dayak, Sea, woman.
1070, 1071. Dayak, Sea, chief.
1133. Dayak, Sea, man and girl.
1131. Dayak, Sea, and Kayan.
1128. Dayak, Sea, head feast.
1127. Dayak, Sea, head feast, heads of Punans.
1136. Dayak, Sea, house in course of construction.
1145. Dayak, Sea, house, beehives in.
1147. Dayak, Sea, cloth.
1148. Dayak, Sea, corsets.
1150. Dayak, Sea, currency, gongs and jars.
1155. Dayak, Sea, ear ornaments.
1159. Dayak, Sea, man's coat.
1163. Dayak, Sea, fiddles.
1033. Dayak, Sea, cock fighting.
1160. Drums.
1084. Dulit mountain.
1155, 1157. Ear ornaments.
1164. Harps.
1069. Jungle, track through.
1144. Kadayan house, interior.
1046. Kajaman girl.
1050. Kalabit men.
1051. Kalabit women.
1028. Kalabit smithy.
1048, 1117. Kayans.
1131. Kayan and Sea Dyak.
1151. Kayan baskets.
1024. Kayan camp of hunting party.
1143. Kayan carvings.
1041, 1100. Kayan chief.
1023. Kayan collecting gutta-percha.
1129. Kayan firemaking.
1139. Kayan girl.
1121. Kayan house fortified.
1135. Kayan house, supports of.
1138. Kayan house, interior.
1153. Kayan house, skulls in.
1088. Kayan peacemaking.
1044. Kayan woman with child in sling.
1120. Kayan woman dancing with enemy's head.

1152. Sibop House, carved door.
1083. Sibop village.
1122. Sibop village, tutelary deity.
1058. Sibuyans of Lundu.
1102. Siduans playing nose flute, &c.
1149. Siduans, baskets.
1134. Tanjong woman.
1073. Trusan Muruts.
1029. Tuba fishing, Baram River.
1090. Tutan River, rapid.
1162. Zither, bamboo.

CEYLON.—*Photographed by* DR. C. G. SELIGMANN, 15 *York Terrace, N.W.*

10210. Anuradhapura, on the road to.
10211. Anuradhapura.
10212. Anuradhapura, large Buddha.
10213. Anuradhapura, Dagoba.
10214. Anuradhapura, Dagoba.
10215. Anuradhapura, monolithic pillars.
10216. Anuradhapura, moonstone.
10217. Anuradhapura, Naga Raja.
10218. Anuradhapura, rock temple.
10219. Anuradhapura, shrine in wood.
10220. Anuradhapura, Thuparama Dagoba.
10221. Anuradhapura, tombs of saints.
10222. Bathing lake.
10223. Bo tree.
10224. Bo tree, Pooja to.
10225. Goddess and priest.
10226. Kandy, temple at.
10227. Kandy, temple near.
10228. Kandy, terrace-cultivation.
10229. Kandy, toy shrine.
10230. Kangani and Kali.
10231. Matale, shop.
10232. Matale, Tazia.
10233. Native playing stringed instrument.
10234. Nawalapitya, sacred stones.
10235. Nawalapitya, sacred stones and mango tree.
10236. High priest.
10237. Chief priest, Ruanweli.
10238. Tamil child and charms.
10239. Tamil girl pounding rice.
10240. Tamil house.
10241. Tamil lines.
10242. Tamil lines and landscape.
10243. Tamil men.
10244. Tamil women.
10245. Tamil women.
10246. Tea coolies.
10247. Tea-picking.
10248. Tea-picking.
10249. Tea-picking.
10250. Tea-weighing.
10251. Terrace-cultivation.
10252. Terrace-cultivation (see also 1022
10253. Thurapama, shrine at.
10254. View of hills.

INDIA.

SOUTHERN INDIA, TODAS.—*Photographed by* DR. W. H. R. RIVERS, *St. John's College, Cambridge. (The references are to Dr. Rivers's 'The Todas,' where a description of the photographs will be found.)*

9001. Toda man, p. 19.
9002. Toda man, side face, p. 20.
9003. Toda woman, p. 21.
9004. Toda woman, side face, p. 22.
9005, 9006. Toda village, pp. 25, 27.
9007. Toda house, p. 28.
9008. *Kaimukhti* salutation of Todas, p. 31.
9009. Toda women pounding and sifting grain, p. 33.
9010. *Kalmelpudithti* salutation of Todas, p. 35.
9011, 9012. Toda dairy, pp. 44, 46.
9013. Toda method of churning, p. 51.
9014. Toda dairy-vessels, p. 59.
9015. Dairy and dairyman, p. 63.
9016. Dairyman saluting threshold, p. 65.
9017. Dairy (*kudrpali*), p. 67.
9018. Toda *wursol*, p. 75.
9019. Dairy and calf-house, p. 77.
9020. Salutation of *palol*, p. 95.
9021. *Palol* in attitude of prayer, p. 96.
9022, 9023. Method of carrying dairy-vessels, pp. 125, 127.
9024. Dairy and stones called *neurzülnkars*, p. 129.
9025. *Neurzülnkars*, p. 130.
9026. *Palol, kaltmokh*, and *neurzülnkars*, p. 141.
9027. Stones called *irnörtkars*, p. 299.
9028. Scene of *irnörtiti* ceremony, p. 301.
9029. Salutation called *nersatiti*, p. 304.
9030. Seclusion-hut for Toda women, p. 314.
9031. Boy holding imitation bow and arrow, p. 393.
9032. Methods of Toda dress, p. 573.
9033, 9034. Child, to show method of shaving head, p. 577.
9035. Drill method of making fire, p. 582.
9036. Badaga greeting Toda, p. 631.
9037. Sacred stones, p. 646.
9038. Dairyman taking food, p. 46.
9039. Kuriolv and Pilimurg, Toda man and woman, p. 552.
9040. Kuriolv, p. 551.
9041. Kuriolv and Meilitars, p. 564.
9042. Group, pp. 30, 535.
9043. Toda man, p. 575.
9044. Kodrner (7), Karseidi and Kerkwodr (8), p. 14.
9045. Toda men.
9046. Toda women.
9047. Toda acting as forest ranger.
9048. Toda village, p. 29.
9049. Village of Umgas, p. 673.
9050. Village of Pishkwosht, p. 656.
9051, 9052. Village of Naters.
9053. Stones called *Teuar*, p. 656.
9054 Nerpeiker, p. 206, and hill Tikalmudri, p. 205.
9055. View from Modr showing the hill Koti, p. 291.
9056. *Ti* dairy at Modr, p. 86.
9057. *Ti* buffaloes at Modr.
9058–9060. Milking scene, pp. 53, 54.
9061. Dairy at Kanodrs, p. 80.
9062. Tarvali at Tovalkan with *palikartmokh*, p. 655.
9063. Ordination ceremony, p. 146.
9064. Ordination candidate saluting threshold of dairy, p. 146.

9065. Seclusion-hut, pp. 314, 325.
9066. Ceremony after seclusion, p. 328.
9067, 9068. Funeral-hut and pen, pp. 340, 341.
9069. Old funeral-place, showing tree growing in pen.
9070. Funeral-post, p. 350.
9071. *Erkumptthpimi* sacrifice: making fire, p. 277.
9072, 9073. *Erkumptthpimi* sacrifice: prayer, pp. 279, 280.
9074. *Erkumptthpimi* sacrifice: killing of calf, p. 279.
9075. *Erkumptthpimi* sacrifice: passing log and leaves round calf, p. 279.
9076. *Erkumptthpimi* sacrifice: cutting up calf, p. 281.
9077. *Erkumptthpimi* sacrifice: roasting calf, p. 283.
9078. *Merkalars*, p. 29.
9079. Tamil coolies.
9080. Tamil child.
9081. Bridge at foot of Nilgiris.
9091. Framework of Toda house, p. 584.
9092. Toda memorial mound, p. 440.

INDO-CHINA (FRENCH).—*Photographed by* Dr. C. G. SELIGMANN, 15 *York Terrace, N.W.*

10255. Chulon, canoe at.
10256. Chulon, market-place.
10257. Chulon, Chinese temple, interior.
10258. Chulon, Chinese temple, side wall.

AFRICA.

ALGERIA.—*Photographed by* Dr. W. H. R. RIVERS, *St. John's College, Cambridge.*

9082. Rag bush at Old Biskra: seat of marabout.
9083. Rag bush in cemetery at Sidi Okba.
9084. Arab; oasis of Sidi Okba.
9085. Nomad Arabs from camp near Biskra.
9086. Nomad child.
9087. Date market at Biskra.
9088. Barber at Biskra.
9089. Arab boys.
9090. Roman pillar in Old Biskra.

RHODESIA.—Collection, Royal Anthropological Institute.

Photographed by Mr. FRANKLIN WHITE, *Bulawayo.*

Dhlo-Dhlo Ruins.

928. North-east side.
929. North-west side.
930. Enlarged view of part of 928.
931. Enlarged view of part of 929.
932. Entrance in north face.
933. Square corner in north-west side.
934, 935. Portion of north-west side.
936. North-west corner from east.
937. North-west corner from south.
938. Western face.
939. Outer enclosure.
940. Outer enclosure, or guard-house.
941. Entrance to outer enclosure (940).

Zimbabwe: Elliptical ruin.

901. General view from hill ruins.
902. South-west end of chevron pattern.
903. Wall between chevron and west entrance.

904. West entrance.
905. West entrance and wall to north.
906. Continuation of wall northwards.
907. Continuation of wall northwards.
908. Continuation of north and side wall.
909. North-west entrance.
910. North-west entrance to gap in wall.
911. Gap in north wall.
912. Wall, south side of gap.
913. Outer passage and main wall.
914. North entrance.
915. Steps to north entrance.
916. The passage.
917. East doorway in passage.
918. The tower.
919. West wall of tower enclosure and western monoliths on wall.
920. Monoliths near west entrance.
921. Interior, south end; large tower, black courses.
922. Interior, south end; monoliths on wall.
927. Plan of the ruin.

Hill ruins.

924. Doorway, rounded corners, lintels.
925. Doorway, square corners.

Valley ruins.

923. Bird and crocodile carved on soapstone beam.
926. Plaster-covered stonework.

South Africa.—*Photographed by* Miss Ethel M. Hartland, Highgarth, Gloucester.

8002. Bushman,
8004–8015. Bantu, full faces and profiles (see 'Man,' 1907, 35, pl. D).

Sudan, E.—Collection, Royal Anthropological Institute.

233, 234. Nuba native.

Swaziland.—Collection, Royal Anthropological Institute.

80, 82. Boys.
81, 83–94, 101, 102. Women and girls.
83. Kraal, with women and girls.
107. Kraal.

Tonga.—Collection, Royal Anthropological Institute.

95. Boys.
96. Girl.
98, 103, 105, 106. Doctor and attendants.

Zululand.—Collection, Royal Anthropological Institute.

97, 104. Men and boys.
852, 874, 875. Cetewayo.
876. Cetewayo's wives.
853–873, 877–881. Natives.

Photographed by Miss Ethel M. Hartland, *Highgarth, Gloucester*

8003. Zulu witch-doctor's necklace (' Folklore,' vol. xvii, pl. 15).

AMERICA, NORTH.

North American Indians.—Collection, Royal Anthropological Institute.

Crows.

260 Graveyard.
261. Group of chiefs.
262. Interior of lodge.
263. Group of squaws.

Pawnees.

264. Village.
265. Painting on buffalo robe.
267. Adult male.

Ponca.

210, 211. Composite photo of eight adult male skulls.

Salish.

454. Ethnographical objects.
455. Group.
456. Lodges: salmon trap in foreground.
458. Kalispilm lodges.
458*a*. Sweielp lodges.
551–596, 616–646. Men, women, and children.
See also British Columbia.

British Columbia.—Collection, Royal Anthropological Institute.

598, 599. Stone implements.

Queen Charlotte Islands.

602–604. Cumshewa village, with totem posts.
614. Kung village, Virago Sound, with totem posts.
613. Lucy Island: Village, with totem posts.
612, 613. Massett village, with totem posts.
605–608. Skidaus village, with totem posts.
609–612. Skidegate village, with totem posts.
601. Tan-oo or Klue village, with totem posts.

See also North American Indians: Salish.

United States.—Collection, Royal Anthropological Institute.

Utah.

461, 462. 'Aztec Springs': ruined city.
469–472. Hooven Weep River: ruined fortress.
463–465. McElmo River: ruins.
459, 460. Manco Cañon: ancient ruins.
451–453. Rio de Chilly: Pueblo.

AMERICA, SOUTH.

Bolivia.—Collection, Royal Anthropological Institute.

246, 247. Chikuachi: Two dried female bodies.

British Guiana.—Collection, Royal Anthropological Institute. *Photographed by* Sir E. F. im Thurn, K.C.M.G.

157. Ackawoi house.
146. Arawack.
147–149. Arawack whip game.

150. Arawack women: rattle game.
151. Arawack women beating time for dances.
152. Arawack and Portuguese half-breed.
153–155. Arawack and Spanish half-breed.
116–137. True Caribs.
138. Carib and Scotch half-breed.
108. Macusi.
109–114. Macusi games.
139, 140. Warrans.
141–143. Warran shield game.
156. Warran village.
144, 145. Warran and African half-breed.

NEW GRANADA, OR UNITED STATES OF COLOMBIA.

275. On the Rio Nerena.
277. On the Rio Truando.

AUSTRALIA.

Collection, Royal Anthropological Institute.

223, 224, 250, 287–296, 801–820. Natives.

Tasmania.

222. Skull.
225–232. Natives.

OCEANIA.

ELLICE ISLANDS.—Collection, Royal Anthropological Institute.

186–193. Groups of natives.

FIJI ISLANDS.—Collection, Royal Anthropological Institute.

832–851. Natives.

NEW CALEDONIA.—Collection, Royal Anthropological Institute.

297. Native man: profile, front and back views.
298. Native man, front view.
299. Native man, profile and front views.

NEW HEBRIDES.—Collection, Royal Anthropological Institute.

Photographed by Commander BOYLE T. SOMERVILLE, R.N.

37. Specimens of spears.
42. Specimens of clubs.

Efati Island.

20. Drums at Leleppa.

Epi Island.

24*a*. Native.

Espiritu Santo.

26, 28. Two skulls.

Mallicollo.

1, 2. Dancing grounds.
6. Sacrifice of pig.
8. Skulls.

Port Sandwich.

4. French settlement, with canoes.
5. Three natives.
12. Profile of native.
13. Two natives.
14. Heads of two natives.
15. Native shooting fish.
18. Pig-paying dance.
19. Dancing grounds.
21. Group of natives.
22. Native.
23. Natives in canoe.
29. Dancing grounds and drums.
35. Canoe.
39. Group of natives.
40. Native boy.
41. At the pig-paying ceremony.

Saangofa Village.

38. Old chief.

Tongariki Island.

25. Chief Sasamaki.

Tongoa.

32. Young man.
33. Group of chiefs.
34. Group of natives.

Uripiv.

3. Stone altars on dancing grounds.
7. Two natives.
9. Stones of worship.
10, 11. Shed supported by carved pillars.
16, 17. The Maki dance.
27. Rack of sacred pig's tusks.
30. Widow of chief.
31. Natives.
36. View during the Maki dance.

NEW ZEALAND.—Collection, Royal Anthropological Institute.

821–830. Maoris.
831. Maori house.
831*a*. Maori carved post.

SANDWICH ISLANDS.—Collection, Royal Anthropological Institute.

203, 204, 216. Composite photographs of seven adult male skulls.

SOLOMON ISLANDS.—Collection, Royal Anthropological Institute.

Photographed by Commander BOYLE T. SOMERVILLE, R.N.

New Georgia.

52, 53. Group of natives, Munggeri.
54. Natives.
56. Native king.
57. Natives.
59. Canoe.
60. Native with canoe.
61. Native making fire.
62. Grave and skull house.
63. Olawatu, or sacred island.
64. Native playing flute.
65. Boy playing jew's harp.
66. Boy playing jew's harp, European form.
67, 68. Prepared head, Rubiana.

Megalithtic Remains in the British Isles.—Interim Report of the Committee, consisting of Professor W. RIDGEWAY (*Chairman*), Dr. G. A. AUDEN (*Secretary*), Professor J. L. MYRES, Mr. G. L. GOMME, *and* Mr. F. W. RUDLER, *appointed to report on the best means of Registering and Classifying systematically Megalithic Remains in the British Isles.*

THE Committee appointed to report upon the best means of registration and classification of the megalithic remains of Great Britain have devoted their attention to the collection of information relating to the methods employed in several countries (*e.g.*, Norway, Sweden, Denmark, and France).

They have also obtained the views of various persons who have interested themselves in the question, and have secured promises of assistance from various societies. The existence of the Committee has also been brought to the notice of the Society of Antiquaries and to the Conference of Archæological Societies held in London in July 1907.

Archæological and Ethnographical Researches in Crete.—Report of the Committee, consisting of Sir JOHN EVANS (*Chairman*), Professor J. L. MYRES (*Secretary*), Professor R. C. BOSANQUET, Dr. A. J. EVANS, Mr. D. G. HOGARTH, Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

THE Committee regret that unforeseen circumstances have prevented Mr. C. H. Hawes from completing his projected memoir on the results of his examination of the ancient and modern population of Crete, and from making use of the Association's grant for the purpose of further exploration of the same kind.

The Committee hope, however, that it may be possible to bring the work already undertaken to a close without great delay; and therefore ask to be reappointed, with the unexpended balance 100*l.*

The Lake Village at Glastonbury.—Ninth Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Professor W. BOYD DAWKINS (*Secretary*), Sir JOHN EVANS, Dr. ARTHUR J. EVANS, Mr. HENRY BALFOUR, Mr. C. H. READ, *and* Mr. A. BULLEID. (*Drawn up by* Mr. ARTHUR BULLEID *and* Mr. H. ST. GEORGE GRAY.)

THE excavations at the Lake Village near Glastonbury were reopened this year on May 6 under the joint superintendence of Mr. Arthur Bulleid and Mr. H. St. George Gray, and digging was carried on for six weeks. The ground explored covered some 1,080 square yards, situated in the N.W. quarter of the village, together with half a dwelling-mound near the S.W. border. The number and variety of the 'finds' were below the average, but the structural discoveries compared favourably with those of other seasons. During the digging this year several areas of clay were discovered hitherto unrecognised, bringing the total number of 'mounds' up to 89. Dwelling-mounds, or areas of clay, Nos. 66, 84, 85, 86, 87, 88, and 89, together with the intervening spaces of level ground, were explored; dwelling-mounds Nos. 73 and 75, partly examined in 1906, were completed, as were also portions of the following dwellings left from former years: Nos. 13 (1896), 34 (1898), and 81 (1905).

This completes the systematic examination of the entire site, with the exception of the small piece of ground on which the shed stands. The excavations were begun in 1892, and have been in progress sixteen years, with an interval of five years.

The following points of interest were noticed in the different mounds:—

MOUND 13.—The E. half of this mound was excavated in 1896. The W. half was examined this year, and was found to be composed of several layers of yellow and blue clay, the total thickness of which near the central picket measured 9 feet 3 inches. The lower layers of clay were kept in place along the S.W. margin by a line of piles and wattle-work. No hearths were discovered on any of the floors A well-defined line of wall-posts was found bordering the N. margin of Floor I. The substructure under the W. half of the mound was strong, and was composed of two layers of timber with much compressed rush and brushwood under. The upper stratum of timber was arranged lengthways, chiefly in an E. and W. direction; the lower N. and S. The upper timbers varied from 6 inches to 9 inches in diameter, the lower from 9 inches to 14 inches. The greatest thickness of the layers of rush and brushwood measured 2 feet 3 inches.

The only objects of interest found in the W. half of Dwelling 13 were: H 364, W 116, and X 74.

MOUND 66.—This dwelling-mound was of small size, situated in the N.W. quarter of the village, lying E. of Mound 74 and N.E. of Mound 75. It was composed of two floors, the upper made of yellow and the lower of dark-grey clay. The greatest depth of clay near the central picket was 18 inches, and the greatest diameter E. and W. 19 feet. There were indications of a hearth on Floor I. covering an area 5 feet 6 inches in diameter. The hearth belonging to Floor II. was a circular area of clay measuring 5 feet in diameter. At a depth of 5 inches under this a gravel hearth was found 3 feet 8 inches in diameter, and below this two

superimposed hearths of baked clay of smaller dimensions. The substructure was not strong, chiefly consisting of brushwood with a few pieces of timber, the two together averaging 12 inches in thickness. A mortised beam of oak with pile driven through *in situ* was found under the clay in the S. quarter of the mound; the beam was lying lengthways in a N.W. and S.E. direction.

Amongst the 'finds' of interest were the following: H 360 to 362, and X 73.

MOUND 73.—Only a small part of the S.E. quarter of this dwelling-mound remained for examination from season 1906. No 'finds' of importance were discovered except H 359, and no additional points of interest were noticed in regard to the substructure.

MOUND 75.—Dwelling-mound 75 was of large size, situated in the N.W. quarter of the village, lying S.E. of Mound 74 and E. of Mound 73. It was composed of four floors of yellow clay, with nine superimposed hearths. The greatest diameter N. and S. was 33 feet, and the greatest depth of clay near the central picket was 2 feet.

Floor I., measuring 27 feet N. and S. by 24 feet E. and W., was partially overlapped by Mound 74 along the N.W. margin; the hearth was a circular area of baked clay about 3 feet in diameter. Floor II. measured 29 feet N. and S. by 32 feet E. and W.; the hearth was made of baked clay and measured 3 feet in diameter. Floor III. was of much smaller dimensions than those above, and the diameter was not easily determinable; the hearth was made of baked clay, and was of similar size to Hearth II. Floor IV. was of small size, and the area of clay was largely occupied by a series of six superimposed hearths; the uppermost, Hearth IV., was made of gravel and measured 3 feet 6 inches in diameter; Hearth V. was composed of baked clay, of circular outline and convex in section, measuring 3 feet 10 inches in diameter; Hearth VI. was made of stone, but was incomplete when found, and consisted of three large stone slabs, covering an area of 2 feet 6 inches; Hearth VII. was also made of stone, and was partly overlapped by Hearth VI. The pavement was composed of fourteen small slabs of lias, much cracked by heat, covering an area of 4 feet 10 inches in diameter; under Hearth VII. there were two small baked-clay hearths (Nos. VIII. and IX.) measuring respectively 3 feet 6 inches and 3 feet in diameter N. and S.; both were of circular outline and slightly convex in section.

The substructure was not strong; under the W. half it consisted of a layer of brushwood, but under the N.E. and S.E. quarters there were large pieces of timber, chiefly arranged in a N.W. and S.E. direction. Under the N.E. quarter of the mound the earth lying on and around the superficial layers of brushwood was very black, and contained a quantity of incomplete animal bones, some of the fragments being calcined, and fragments of pottery. This area appeared to have been lived upon before the clay was placed in position. In the black earth there were occasional traces of bronze staining, but only small pieces of that metal were observed.

Amongst the objects of interest found in Mound 75 were: A 5, B 407 (1906), B 408 to 411, C 30, E 57, E 268 (1906), E 269, E 271 to 274, F 378, H 358, H 363, I 106 (1906), I 107, I 108, K 31, L 49, N 8, P 179, P 180, W 72, W 95.

MOUND 81.—The S. half of this mound was excavated in 1905 and completed this year. It consisted of one floor, and at 5 feet 6 inches N.

of the central picket the clay was 7 inches thick, and was covered by a layer of black earth, the average thickness of which was 3 inches. No hearth or doorstep was discovered, and no line of wall-posts was traceable along the N. margin of the clay. The substructure was not strong, and consisted of a layer of brushwood and a few logs arranged lengthways in a N.N.E. and S.S.W. direction.

The only objects of importance discovered were : S 45, W 111.

Area of Clay 84.—This dwelling-site, unrecognised before digging, was situated S. of Mound 83, the N. and E. margins being overlapped by the clay of that mound for the space of 13 feet. This dwelling-site, consisting of two floors and three hearths, was composed of a mixture of yellow and grey clay, the greatest thickness of which was 9 inches, and the greatest diameter E. and W. 23 feet. No hearth was discovered belonging to Floor I. The surface of Floor II. was covered with a well-marked layer of black earth, averaging 3 inches thick. Two small baked-clay hearths were found in the E. quarter, placed eccentrically to the middle of the mound, and not superimposed. The margin of Hearth I. overlapped the N.W. margin of Hearth II. Hearths I. and II. measured 3 feet 9 inches and 3 feet 6 inches in diameter respectively. Hearth III. was found under Floor II., placed in the centre of a small area of clay measuring 7 feet 6 inches in diameter E. and W. : it was composed of seven slabs of lias embedded in the clay, the greatest diameter of the pavement being 2 feet 10 inches. The stones were unevenly arranged with an irregular outline and much cracked by heat. The hearth was covered and surrounded by a layer of black fire-ash 2 or 3 inches thick. No door-step or wall-posts were discovered. The substructure was unimportant.

Amongst the objects of interest found in this mound were : D 75, D 76, E 270, G 26, Q 53, W 54. The black earth covering Floor II. contained a quantity of peas and some fragments of bone and unornamented pottery ; a triangular loom-weight was also dug up.

Area of Clay 85.—This area, not noticeable before digging, was of somewhat quadrilateral outline, and composed of one layer of yellow clay. It was situated in the N. central part of the village, lying E. of Mound 66, N.E. of Mound 75, and W. of Mound 62. The greatest diameter was 21 feet, and the greatest depth of clay near the central picket was 14 inches. No hearth, door-step, or line of wall-posts could be traced. The substructure was well marked, consisting of a layer of brushwood supported by pieces of timber, 9 inches in diameter, arranged chiefly in an E. and W. direction.

The only 'find' of importance was a piece of cut wood, X 71. When trenching the ground N. of the clay, two alder stumps with roots *in situ* were discovered embedded in the peat, and in the same position the skull of a small horse was uncovered.

Area of Clay 86.—This area was of irregular oval outline made of yellow clay 3 to 5 inches thick, and situated S. of Mound 84. No rise in the ground over it was noticed before digging. The greatest diameter measured 18 feet 6 inches. The substructure was unimportant, consisting of a layer of brushwood and a few pieces of rough timber. No hearth, wall-posts, or relics were discovered.

Area of Clay 87.—This was a small area of yellow clay of irregular oval outline situated N. of Mound 32 and N.W. of Mound 34. It was not noticed before digging. The greatest diameter was 7 feet 6 inches,

and the greatest thickness of the clay 6 inches. The substructure was unimportant, and no objects were found either on or in the vicinity of the clay.

AREAS OF CLAY 88 AND 89.—These were small irregularly shaped and thin areas of clay situated N.E. of Mound 31. The greatest diameters of both were 10 feet 6 inches, and the depth of the clay varied from 3 to 5 inches. Nothing noteworthy was found regarding the substructure, and the only numbered 'finds' were two whetstones, S 43 and S 44, found near the W. margin of Clay-area 89.

MOUND 34.—This site, partly excavated in 1898, was composed of two floors of yellow clay, and situated N. of Mound 33, by which mound it was overlapped along the S. margin. The greatest diameter of the clay was 22 feet, and the greatest thickness 11 inches. An incomplete line of wall-posts was noticed along the W. and N. margins of the clay, but no hearth was discovered. The substructure was unimportant, and no objects of interest were found in or near the site. Several alder stumps with roots *in situ* were found embedded in the peat lying N. and N.W. of the clay.

There was a large area of level ground situated between Mound 81 and Areas of Clay 86 and 87, and extending westwards of the latter as far as the boundary of the village. This ground was trenched, but did not yield a single object worth mentioning. It was largely composed of rush peat, and was not piled except near the W. margin of Mound 81 and the N. margin of Mound 84. The ground on which the shed stood was included in this area.

SHORT DESCRIPTION OF THE RELICS, ALL FOUND IN 1907.

Amber. (A.)

5. Complete bead, translucent orange, found in two pieces, 1¾ foot apart; ext. diam. 23 mm.; thickness 6 mm.; diam. of hole 6·5 mm.; section oval. The edge in one part for a distance of 7 mm. shows considerable signs of wear, the depression being slightly concave. Mound 75.

Bone Objects. (B.)

408. Two smooth metatarsal bones of sheep or goat, each with condyle complete at the distal end; a circular hole at the proximal end; in one case the articular surfaces of this end have been cut off. Mound 75.

409. Part of the shaft of a sheep's metatarsus, length 31·2 mm.; max. width 9·2 mm.; carefully trimmed, and having a circular, bevelled perforation (min. diam. 3·3 mm.) through the middle of one of the sides on the greatest width of the object; ornamented with faintly incised diamonds, intersected by parallel lines arranged transversely. Mound 75. A precisely similar object (B 28), but unornamented, length 30·4 mm., was found previously in the village.

410. Calcined piece of smooth bone of oval section, 11 mm. by 9·5 mm., showing marks of a fine saw at both ends; max. length 19 5 mm. Mound 75.

411. Polished metacarpus of sheep, with small oval hole at the proximal end. Mound 75. This bone belonged to a sheep about 2 feet 1 inch in height at the shoulder.

A horn-core of *Bos longifrons*, with a fairly deep saw-cut 2 mm. wide encircling the core near the base, was found in the peat below the clay of Mound 13 amongst the wall-posts.

Crucibles. (C.)

30. Small portion of a crucible, with fused bronze still adhering to the side. The knobbed end of a small bronze pin was found with it. Mound 75. Mr. Clement Reid, F.R.S., believes that the clays found in association with the Somerset lias, or oolite or the alluvium, would not be at all suitable for the manufacture of the

crucibles found in the village; and he thinks they were probably made from material procured from the fire-clay and gritty gannister beds of the Bristol coalfield.

Baked Clay. (D.)

75. Small globular bead of baked clay of a light reddish-brown colour; roughly made; ext. diam. 7·2 mm.; thickness 6 mm.; diam. of hole about 2·8 mm. Mound 84.

76. Very roughly made globular bead of a reddish-brown colour; ext. diam. 10 mm.; average thickness 8·5 mm.; diam. of hole 3·8 mm. Mound 84.

Baked clay beads have not previously been found in the village.

A few pieces of wattle-marked clay were found in Mound 75, S.E. quarter.

One fusiform sling-bullet. Mound 75.

Piece of baked clay showing clear impressions of skin-marks of the fingers.

A large complete triangular loom-weight with sides practically equilateral was found in Mound 66; the corners are rounded, the faces flat; thickness averages $3\frac{3}{4}$ inches: it is perforated across each corner for suspension.

Bronze Objects. (E.)

57. Small, gracefully formed fibula, found damaged, but now almost completely restored; of slender make and of early La Tène type, composed of a continuous piece of wire, nowhere exceeding 1·5 mm. in thickness. The pin and bow are perfect, but the spring and retroflected end of the brooch have been broken; the coil appears to have completed four and a half turns on either side of the head of the bow, the two sides being connected by the wire running along and almost touching the back of the coil. The catch-plate and the tail were absolutely continuous in the perfect brooch, the retroflected end being bent back to touch the summit of the bow and secured to it by means of a rounded and moulded collar 2·9 mm. in diam. Length from tip of pin to back of spring 39·5 mm. Mound 75. This is not only one of the smallest fibulæ found in the village, but is probably the oldest in type, with the exception of E 173, found in 1898, which may antedate it slightly.

269. Small hook, perhaps the fastening of a belt; length 14·3 mm.; max. width 7·5 mm.; ornamented by a slightly incised line following the sides of the outer face. Mound 75.

270. The greater part of a small spiral finger-ring, the ends tapering to a blunted point; found in seven pieces; composed of a continuous strand of flat wire measuring 1·7 mm. by 0·7 mm. Mound 84. It is similar in type to E 127, found near Mound 11 in 1896.

271. Two small lumps of bronze. Mound 75.

272. Complete spiral finger-ring, composed of finer wire than any other ring from the village; the material completes about $2\frac{1}{3}$ turns, and is of oblong section; int. diam. about 14 mm. Mound 75. Of the same type as the ring E 88 found in 1895. A precisely similar ring was found in a crannog at Lochlee, Tarbolton, Ayrshire, and is figured in Munro's 'Scottish Lake Dwellings,' p. 132.

273. Piece of thick sheet bronze; length 81 mm.; max. thickness 2·7 mm.; flat, smooth faces. The straighter edge shows evidence of having been partly cut through, perhaps with a hammer and chisel, and then bent back and broken off. Mound 75.

274. One-half of the ring of a penannular brooch, the ext. diam. having originally been 29 mm.; the pin is deficient. In section the ring is plano-convex, the convex surface being ornamented by a continuous row of transverse incisions. One of the terminals remains; it is slightly expanded, and measures 3·7 mm. in width. Mound 75. A ring-brooch ornamented in a similar manner was found in a crannog at Buston, near Kilmaurs (see Munro's 'Scottish Lake Dwellings,' p. 227).

Flint. (F.)

378. Scraper with chipped and bevelled edge; length 36·5 mm. Trenching E. of Mound 75.

Flint flakes were found as follows: Three in Mound 13 (including one with secondary chipping); one in Mound 66; one W. of Mound 66; five in Mound 75; one in Mound 81; one with secondary chipping in Mound 85; and two in Mound 89.

Piece of burnt flint in Mound 66; another piece in Mound 75; and a third piece in the trenching to the S. of Mound 75.

Glass. (G.)

26. About three-eighths of a small translucent blue glass bead, 6 mm. thick, and originally about 9·5 mm. in diam. Mound 84.

Antler. (H.)

358. Well-preserved object consisting of a complete tine of red-deer cut off at the base; length 190 mm. ($7\frac{1}{2}$ inches) on the outer curve; max. thickness at the cut end 21 mm. At 6·5 mm. from this sawn end is a transverse perforation, about 4·2 mm. in diam. This end has been slightly notched for a width of about 14 mm., and there is a plain bead round the head of the object. The tine is further ornamented by a roughly cut slight incised line encircling the object at 28 mm. from the head. Mound 75. A worked tine of this type has not previously been found in the village.

359. Worked tine of red-deer in a somewhat friable condition; present length of the outer curve 113 mm. It is perforated by two holes laterally, the broken one at the base being about 6 mm. in diam., the larger hole (9 by 8 mm.) being 35 mm. from the tip of the tine. Probably a cheek-piece of a horse's bit. Mound 73. Judging from the frequency with which these side-pieces of bridle-bits, of varying types, have been found in the village, the horse must have been common among the lake-dwellers, not necessarily on the site of the village, but also in the neighbouring hill-country. This is not altogether borne out by the number of remains of horse found on the site, a far greater proportion of remains of oxen having been discovered. On the other hand, it is quite probable that many of these so-called cheek-pieces were used for other purposes at present unknown.

360. Finely worked object made from a red-deer tine, sawn square at both ends; length on the outside curve 118 mm. It has finely moulded ends, and in this respect is unlike anything of antler found in the village. Both the moulded ends consist of ridges (ornamented with encircling incised lines) with a groove between. The moulding at the larger end is 15·5 mm. wide, at the smaller end 10 mm. Just below the larger moulding is a circular perforation (diam. 6·7 mm.) bored transversely on the line of the greatest width. At a short distance within the moulding, on one face only, is an incised dot-and-circle. Use unknown. Mound 66.

361. Handle of antler for iron awl, traces of the corroded iron still remaining embedded in the smaller end of the handle. The object was sawn off square at both ends, the length on the outer curve being 48 mm.; double incised lines as ornament encircle both ends of the handle. Mound 66.

362. Large piece of stag's antler of bi-convex section, with large tranverse perforation, not quite circular, but averaging 17·5 mm. in diam. Probably the head of a hammer. It is in good preservation, and is of somewhat different character from the majority of antler hammers found in the village. Marks of blows are seen on one side. Max. length 72 mm.; max. girth 174 mm. Mound 66.

363. Object of red-deer tine, roughly cut, somewhat expanded, or knobbed, at the larger end; through this enlargement, across its greatest width, a circular perforation (diam. 5 mm.) has been bored; and at 23·5 mm. from the smaller end there is a perforation (max. diam. 7 mm.) in an opposite direction. The object shows groups of knife-cuts in two places. Length on the outer curve 101 mm. Perhaps a cheek-piece of a bridle-bit. Mound 75.

364. Worked red-deer antler with a roughly cut slit at the base, which has been broken. This slit may have been intended for the insertion of the tang of a knife or other cutting implement, but if used as a handle it was a most uncomfortable one for grasping. Mound 13.

Iron. (I.)

107. Much corroded pointed end of a large iron object, perhaps part of a file; length 92 mm.; max. width about 28 mm. Mound 75.

108. Very long iron bolt, found in a much corroded condition in five pieces, but subsequently cleaned; total length 258 mm. (about $10\frac{1}{8}$ inches). The head is of oblong form, measuring 24 mm. by 16 mm.; height of head about 9 mm. At a short distance from the head the bolt is of circular section, with a diameter of 12 mm., tapering to about 10 mm. at the smaller end. Mound 75.

A fragment, probably of an iron ring (unnumbered), was found below the clay of Mound 73.

Kimmeridge Shale. (K.)

31. About one-third of a finely turned and polished armlet, which when complete was 78 mm. in ext. diam.; the substance is circular in section, 9 mm. in diam. Mound 75.

Lead and Tin. (L.)

49. Slightly curved bar, apparently of tin, surface somewhat oxidated; quadrangular section, the dimensions of the sides varying from 7 by 6·5 to 9·2 by 7 mm.; both ends broken off; total length on the curve 146 mm. ($5\frac{3}{4}$ inches). Mound 75.

Animal Bones. (N.)

8. Feet bones apparently of beaver. Mound 75.

An average quantity of animal remains was collected from the 1907 excavations, including a lower jaw of horse which belonged to an animal about 12 hands 3 inches in height (the size of our New Forest pony), and a lower jaw of ox which gives an estimated height at the shoulder of 3 feet 7 inches (midway between the size of the average Kerry and Alderney cows). Bird-bones have been rather more plentiful this year than for several years past. They include several bones of *Grus cinerea* and others of *Pelecanus crispus.*

Pottery. (P.)

179 The greater part of an ornamented globular bowl, height $4\frac{13}{16}$ inches; ext. diam. at rim, 6 inches; max. ext. diam. $7\frac{1}{4}$ inches. Found in many fragments (now restored). Ornamented with a band of decoration (width $1\frac{1}{8}$ inch) just below the rim, consisting of a row of chevrons, pointing upwards, filled with crossed lines parallel to the sides. This is a common design in the village. As is the case with so many of these cooking-pots, soot was found adhering to the outer surfaces in some places. Mound 75. About one-quarter of a similar bowl, with the filled chevrons pointing downwards, was found this year in Mound 66.

180. The rim and about one-half of an ornamented globular bowl, the ext. diam. of the rim being $5\frac{3}{4}$ inches; max. ext. diam. of the pot $6\frac{1}{2}$ inches. Found in several fragments (now restored). Ornamented with a band of decoration (width $2\frac{3}{16}$ inches) on the bulge of the vessel, consisting of two rows of rhomboids divided from each other by double incised lines; the whole is bounded horizontally by four roughly incised lines at the top and three at the bottom. Alternate rhomboids are filled in by oblique parallel lines, the others being quite plain Mound 75.

Compared with some former years, the number of fragments of pottery discovered this year was below the average, and ornamental pieces were conspicuous by their scarcity. A few ornamental fragments, however, were found in Mounds 66, 75, and 85. In the Area of Clay No. 89 two fragments of decorated rim of a much fired dish with straight sides were found, similar in character to the open bowls (P 171 and 172), containing charred wheat, found in 1905 in Mound 70.[1]

Querns. (Q.)

53. Upper stone of a saddle-shaped quern of quadrangular section in both directions; the smooth face is very slightly concave; rounded corners; length $9\frac{7}{8}$ inches; max. width of smooth face $6\frac{1}{8}$ inches. Mound 84.

Stone Objects. (S.)

43. Whetstone of fine sandstone, worn on all the surfaces and showing indications of prolonged use. Length 123 mm.; max. width 26 mm.; max. thickness 23 mm. Clay-area No. 89.

44. Thin flat sharpening-stone of quadrangular section; made from a very fine piece of slatey sandstone; length 79 mm.; max. width 25 mm.; max. thickness 7·2 mm. Its interest centres chiefly in the fact that it is much scored on both faces

[1] *Proc. Som. Arch. Soc.*, vol. li., pt. 2, pl. v.

by faintly marked irregular incisions, probably caused by sharpening needles. Clay-area No. 89.

45. Irregularly shaped whetstone of fine sandstone much used on the edges and both faces; length 136 mm.; max. width 45 mm.; max. thickness 16 mm.; section bi-convex. On one face there is a deep pointed groove in which awls have been sharpened. Mound 81.

Small rounded pebbles, probably used in games.—Three found in Mound 75.

Whetstones, mostly having slightly convex faces.—Four in Mound 75; two in Mound 84. One found on the second floor of Mound 75 bears signs of considerable abrasion along one edge.

Other Stone Objects.—Two large smooth pebbles found in Mound 66; another in Mound 75. Stone muller (?) found in Mound 66.

Spindle-whorls. (W.)

54. Oval sandstone disc, 44 by 40 mm.; max. thickness 15·5 mm.; with incipient holes on both faces, and evidently an unfinished spindle-whorl. Mound 84.

72. Heavy spindle-whorl of sandstone, reddish-grey in colour; the diameters vary from 57 mm. to 59 mm.; max. thickness 17·3 mm.; slightly rounded sides; one face flat, the other rather uneven. The hole is eccentric and countersunk a little on one face; max. diam. 8·4 mm. Mound 75.

95. About three-quarters of a baked clay spindle-whorl of bi-convex section. The clay contains grains of quartz and other stone. Diameter 44 mm.; max. thickness 21 mm.; max. diam. of perforation 10 mm. Trenching E. of Mound 75.

111. Oval spindle-whorl, 58 mm. by 50 mm.; max thickness 9·5 mm.; made from a piece of skull-bone of ox or horse. The perforation, which is not quite centric, is bevelled on both faces; max. diam. 7·6 mm. Mound 81.

116. Globular spindle-whorl of baked clay with smooth surface, but somewhat distorted; bi-convex section; max. diam. 37·3 mm.; max. thickness 30 mm. The perforation is 5·7 mm. in diameter. Mound 13.

Wooden Objects. (X.)

71. Piece of worked oak, one end damaged, part of a larger object. Mound 85. The piece was 37 inches long, with an average width of 6 inches, tapering for 9 inches towards the complete end to 2 inches. The upper surface flat, the lower slightly convex; the inner border concave, the outer convex. Projecting from the inner concave border at right angles to the upper surface was a tongue 3 inches high beginning at $11\frac{1}{2}$ inches from the perfect end and running the entire length of the piece. In cross-section the tongue was plano-convex. The use of the piece is unknown. Two objects of somewhat similar outline were discovered during the excavations of 1894.

73 Plug or stopper cut out of one piece of oak; the greatest length measured $3\frac{7}{16}$ inches, and the greatest width $1\frac{9}{16}$ inches. The transverse section was circular; at a distance of $1\frac{7}{8}$ inch from the larger end the wood was notched in from $\frac{3}{16}$ to $\frac{1}{4}$ inch deep, forming a shoulder; the diameter of the plug at this level measured $1\frac{3}{16}$ inch, gradually tapering towards the small end to $\frac{3}{4}$ inch. Mound 66.

74. Piece of worked oak part of a larger object; greatest length 22 inches; greatest width 6 inches. In cross-section it was plano-convex and $3\frac{3}{4}$ inches deep; at $3\frac{1}{2}$ inches from the complete end the convex surface of the wood was semi-circularly notched in for $1\frac{1}{2}$ inch; at 2 inches from the complete end it was cut again to form a squared mortise, 2 inches deep by 1 inch wide. Mound 13. A similar piece of oak with one end notched and mortised was found in Mound 9 during the excavations of 1896.

Miscellaneous.

Red colouring matter was found in Mound 75.

Excavations on Roman Sites in Britain.—Interim Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), Professor J. L. MYRES (*Secretary*), Sir EDWARD BRABROOK, Dr. T. ASHBY, Professor R. C. BOSANQUET, *and* Professor W. RIDGEWAY, *appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.*

THE Committee have been in communication, as in former years, with those who are responsible for excavations on Roman sites in Britain, and have received satisfactory reports as to the results of the work which its previous grants have permitted to be undertaken.

The early date of this year's meeting, and other circumstances, have prevented the Committee from assigning definitely the grant made at the York meeting to the excavations planned for the summer and autumn of 1907; but the Committee are satisfied that the grant may be expended profitably in continuation of work actually begun, apart from the question of fresh subsidies.

The Committee therefore ask to be reappointed, with the unexpended balance 15*l.* and a further grant.

The Ductless Glands.—Report of the Committee, consisting of Professor SCHÄFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A. B. MACALLUM, *and* Dr. L. E. SHORE. (*Drawn up by the Secretary.*)

DURING the past year attention has been directed to the islets of Langerhans in the elasmobranch fishes, and the study of the pancreatic elements in these animals has, we believe, shed fresh light on the question as to the morphology of the islets of Langerhans.

The groups of lightly staining cells arranged here and there around the smaller ducts of the elasmobranch pancreas represent the primitive type of islet structure in vertebrates.

The intimate relation between duct and secreting cavity is of such a nature that it is not always possible to draw any hard-and fast line between the individual cells of the two structures. This has been pointed out by Laguesse in the case of the ophidians and the teleostean fishes. The developmental and structural relationship between ductules and 'clear areas' or islets in elasmobranchs has been fully recognised by Diamare, Laguesse, Helly, and other observers. The work of Laguesse, Dale, and ourselves upon the islets of various groups of vertebrates has shown a similar relationship between islets and zymogenous tubules. In elasmobranchs, and especially in Mustelus, we see exemplified in a very interesting manner a primitive state of affairs in which ductule, islet, and zymogenous tubule reveal themselves as portions, variably modified, of the same morphological entity. Thus the connection between 'clear areas' or islets and ductules is obvious, or at any rate very readily perceived. The external layer of cells of the ductules can be seen to be gradually merged into the zymogenous tubules, and occasionally typical zymogenous cells can be seen scattered among the cells of the ductules.

Further, transitions are frequent in elasmobranchs, as in the higher vertebrates, between the clear islets and the zymogenous cells. These transitions occur naturally in the region where ductule, with its masses of islet cells, is becoming continuous with or merged into, the zymogenous tubule.

The 'Metabolic Balance Sheet' of the Individual Tissues.—Report of the Committee, consisting of Professor F. GOTCH *(Chairman)*, Mr. J. BARCROFT *(Secretary)*, *and* Professor E. H. STARLING. *(Drawn up by the Secretary.)*

THE work carried on under the auspices of the Committee in 1906-07 has concerned itself with the following organs: (1) the kidney, (2) the intestines, (3) the heart, (4) the salivary glands. The work has involved further improvements in technique.

(1) *The Frog's Kidney.*—The investigations upon the metabolism of this organ described in the previous report for 1906 have been considerably extended. The influence of sodium sulphate, caffeine, and urea upon the oxygen intake of the organ has been measured when each of these diuretics was perfused through (*a*) the renal portal vein and (*b*) the renal artery. The following table gives some typical results:—

Effect of adding a perfusion through the renal arteries to one through the renal portal veins. Results expressed in c.c. per gramme of kidney per minute.

No.	Oxygen absorbed during perfusion through renal portal vein	O_2 absorbed during simultaneous perfusion through renal portal vein and renal artery	Remarks
1	0·0030 0·0035	0·017 0·011	No diuretic.
2	0·0014	0·0098 0·0010	Same kidney as 1 perfused with 1 per cent. urea.
3	0·006	0·010	No diuretic.
4	0·008	0·025	No diuretic.
5	0·018	0·049	Same kidney as 4 perfused with Na_2SO_4.
6	0·004 0·004	0·008 0·009	No diuretic.
7	0·006	0·028 0·029	Same kidney as 6 perfused with caffeine, sodium benzoate.

The conclusions which the above experiments indicate are as follows:—

(*a*) That the metabolism of the kidney is much greater when the glomeruli are in the circulation.

(*b*) All diuretics which have been used with the exception of urea in certain doses lead to increased kidney metabolism.

In connection with the question of the metabolism of the frog's kidney, determinations have been made of the urea percentage of the frog's blood. For this purpose the blood from two to four pithed frogs has in any given sample been taken by bleeding into alcohol. Estimations of different samples show that the urea amount varies considerably, but the general result indicates a high percentage (0·06 to 0·1 per cent.).

(2) *The Intestine of the Dog.*—A method of estimating the rate of blood-flow through an isolated loop of the intestine by means of the oncometer has been developed and a series of observations upon the gaseous exchange during rest has been made. Attempts to determine how far such gaseous exchanges are to be debited to mucous membrane and to muscle wall respectively have not at present yielded definite results.

Experiments have been conducted in order to follow the gaseous exchange during the absorption of sodium chloride solutions of different strength; all such experiments have shown a distinct increase both in oxygen intake and in carbonic acid output; the rate of absorption of the Cl and of the water has been followed.

In a third series of experiments the gaseous exchange during the absorption of a solution of Witte's peptone was determined.

(3) *The Mammalian Heart.*—Two series of experiments have been in progress as to the metabolism of the heart: (*a*) those in which it was perfused with blood, (*b*) those in which it was perfused with saline solution. In the first series a number of the experiments were made when the oxygen tension in the lungs was reduced either by partial obstruction of respiration or by an atmosphere containing only small quantities of oxygen. It was found that as the arterial blood gets darker the flow through the coronary vessels of the supplied heart increases; at the same time the heart-beat slows and appears to become less efficient. In the second series it was found that with the rabbit's heart perfusion with saline solution at 35° C. is associated with a gaseous exchange of the same order as that found on perfusion with blood (0·02-0·01 c.c. of oxygen intake per gramme per minute). The effect of altering the amount of dextrose in the saline solution is now being studied.

(4) *The Submaxillary Glands.*—A fresh series of researches has been started upon the gaseous metabolism of the submaxillary glands of the cat, with the object of ascertaining the effect produced by the stimulation of the sympathetic, and of thus determining more precisely the relation between cell metabolism and blood-flow. Among the results obtained are positive indications that dilatation of the gland vessels can be produced in consequence of changes which occur in the gland cells. The output of CO_2 as one phase of the whole metabolism is apparently diminished by sympathetic stimulation, whilst the other phase, intake of oxygen, appears to be unaltered or only slightly altered. It is not certain how far the apparent diminution of CO_2 may be accounted for by changes in alkalinity of the gland.

Technique.—Apart from the special technique required in the foregoing experiments, some general aspects of technique have been studied by means of definite series of experiments. Among these are the following:—

The effect of *hirudin* upon the blood and its gases. In regard to this there appear to be no specific effects on the gaseous content of the blood apart from those due to its stimulating the respiratory centres, and this is probably due to anæmia of these centres caused by a passing dilator effect upon the splanchnic vessels, and is thus itself secondary.

The apparatus for measuring the oxygen dissolved in Ringer's solution has been improved and rendered more convenient in form; similar apparatus has given hopeful results in regard to the measurement of CO_2.

The Committee have suffered a serious loss during the year by the death of its senior member, Sir Michael Foster. The Committee would desire to place on record their sense of the loss of one who was mainly influential in their establishment.

No balance remains in the hands of the Chairman, and the Committee, therefore ask to be reappointed with a further grant of 75*l.*; in connection with such reappointment it might be desirable to enlarge the Committee by adding two new members specially cognisant with the subject.

The Effect of Climate upon Health and Disease.—Second Report of the Committee, consisting of Sir T. LAUDER BRUNTON (*Chairman*), Lieut.-Col. SIMPSON *and* Mr. J. BARCROFT (*Secretaries*), Colonel D. BRUCE, Dr. A. BUCHAN, Dr. S. G. CAMPBELL, Sir KENDAL FRANKS, Professor J. G. McKENDRICK, Sir A. MITCHELL, Dr. C. F. K. MURRAY, Dr. C. PORTER, Professor G. SIMS WOODHEAD, Sir A. E. WRIGHT, *and the* Heads of the Tropical Schools of Liverpool, London, and Edinburgh.

IN the following list of the co-opted members of this Committee the names of those who are not members of the British Association are indicated by an asterisk :—

*Aldridge, Lieut.-Col. A. R., R.A.M.C., Simla, India.
*Allbutt, Sir T. Clifford, K.C.B., F.R.S., Cambridge.
*Anderson, Dr. Barcroft, East London.
*Ashe, Dr., Kimberley.

*Balfour, Prof. A., Khartoum.
*Benedict, Prof., Middletown, Conn., U.S.A.
Bohr, Prof. C., Copenhagen.
Branfoot, Surgeon-General A. M., C.I.E., I.M.S., India Office.
*Bulloch, Dr. Wm., London.
*Bulstrode, Dr. H. Timbrell, Local Government Board, S.W.
*Bumm, Präsident, Berlin.

Charles, Sir R. Havelock, K.C.V.O., I.M.S., London.
*Chittenden, Prof. R. H., New Haven, Conn., U.S.A.
*Clarke, Dr., Bulawayo.
*Clemow, Dr. F. G., Constantinople.
*Cumming, Hamilton, Torquay.
Currie, Dr. O. J., Pietermaritzburg.
*Curtis, Dr., London.
Cushny, Prof., F.R.S., London.

*Dixon, Prof. W. E., Cambridge.
*Douglas, Capt. H. E. M., V.C., D.S.O., India.
*Dunbar, Sir Wm. C., Bart., C.B., Registrar-General, London.
*Dunlop, Dr. J. C., Edinburgh.
Dunstan, Prof. Wyndham, F.R.S., London.

*Ellis, Sir H. M., K.C.B., K.H.P., Director-General, Naval Medical Service, London.
*Evatt, Surgeon-General G. J. H., C.B., Camberley.
*Ewald, Prof. A., Berlin.

*Franklin, Surgeon-General Sir B., K.C.I.E., London.
Fraser, Sir Thos. R., F.R.S., Edinburgh.
Gamgee, Prof. A., F.R.S., Montreux.
*Grabham, Dr. M. C., Madeira.
Gregory, Dr. A. J., Cape Town.

*Hann, Prof. J., Vienna.
*Hardy, W. B., F.R.S., Cambridge.
*Harford, Dr. C. F., Leyton.
*Hay, Prof. Matthew, Aberdeen.
Herbertson, Dr. A. J., Oxford.
*Herdman, Dr. Ronald, Filabusi, near Bulawayo.
*Hill, Dr. Leonard, F.R.S., London.
*Hyslop, Dr., Pietermaritzburg.

*Jaffé, Dr., Berlin.

Keltie, Dr. J. Scott, F.R.G.S., London.
*Keogh, Sir A., K.C.B., K.H.P., Director-General, Army Medical Department, London.
*Kerp, Prof., Berlin.
*King, Lieut.-Col., Sanitary Commissioner, Madras.
Kronecker, Prof. Hugo, Berne, Switzerland.

*Langgaard, Prof., Berlin.
Lankester, Sir E. Ray, F.R.S., London.
Latham, Baldwin, C.E., London.
Lempfert, R. G. K., London.
*Leslie, Lieut.-Col. J. T. W., I.M.S. India.
*Liebreich, Prof., Berlin.
Liversidge, Prof. A., F.R.S., Sydney, N.S.W.

MacAlister, Principal, Glasgow.
*Mackenzie, Dr. Leslie, Edinburgh.
*McGregor, Sir Wm., G.C.M.G., F.R.S., Newfoundland.
*McCulloch, Major T., R.A.M.C., India.
*Manners, Dr., Calabar, West Africa.
*Manson, Sir Patrick, K.C.M.G., F.R.S., London.
*May, Deputy-Director-General A. W., Naval Medical Service, London.
*Meek, Lieut.-Col. J., R.A.M.C., Poona, India.
*Melville, Lieut.-Col. C. H., R.A.M.C., London.
*Mitchell, Dr. J. A., Colonial Office, Cape Town.
*Mitchell, Dr. Weir, Philadelphia.
*Moffat, Dr., C.M.G., Uganda, Central Africa.
*Moore, Sir John, Dublin.
*Morgan, Major J. C., R.A.M.C., India.
*Mosso, Prof. Angelo, Turin, Italy.
*Müller, Dr. Franz, Berlin.
*Murison, Dr. P., Public Health Department, Durban, South Africa.

*Nuttall, Dr. G. H. F., Cambridge.

Oliver, Prof. T., Newcastle.
*Osler, Dr. T. H., Cape Colony.
Osler, Prof. W., F.R.S., Oxford.
*O'Sullivan, Lieut.-Col. D., R.A.M.C., India.

Palliani, Prof., Turin, Italy.
*Pearce, Capt. C. R., I.M.S., India.
*Pembrey, Dr. M. S., London.
*Phillips, Dr. L. C. P., Cairo.
*Pinching, Sir Horace, K.C.M.G., Cairo.
Prain, Lieut.-Col. D., C.I.E., I.M.S., Kew

*Raymond, Major G., R.A.M.C., Wellington.
*Reymond, Prof. René du Bois, Berlin.
*Rochfort-Brown, Dr. H., Pietermaritzburg.
*Rogers, Capt. Leonard, Calcutta.
Ross, Major Ronald, C.B., F.R.S., Liverpool.
*Rost, Dr. E., Berlin.
Ruffer, Dr. M. A., C.M.G., Ramleh, Egypt.
*Salmond, Dr. W., Ladysmith.
*Sanders, Dr. A. W., Pretoria.
*Schilling, Dr., Berlin.
*Scott, Major B. H., R.A.M.C., India.
Scott, Dr. R. H., F.R.S., London.
Shaw, Dr. W. N., F.R.S., London.
*Smith, Major Fred, D.S.O., R.A.M.C., India.
Stephens, Dr. J. W. W., Liverpool.
*Strangeways, Dr. T., Cambridge.
*Strong, Surg.-Capt. E. H., Buluwayo.

*Tatham, Dr. John F. W., London.
*Theiler, A., Pretoria.
Todd, Dr. J. L., McGill University, Montreal.
Turner, Dr. G., Pretoria.

*Usmar, Dr. G. H., Bloemfontein.

Wager, Harold, F.R.S., Leeds.
Walker, Dr. G. T., F.R.S., Simla, India.
*Ward, Dr. A. B., Bloemfontein.
*Watkins, Dr. A. H., Kimberley.
*Weber, Dr., Berlin.
*Weber, Dr. Parkes, London.
*Welsh, Fleet-Surgeon, R.N., London.
*Will, Lieut.-Col., R.A.M.C., British East Africa.
*Woeikoff, Prof., St. Petersburg.
*Woodhouse, Lieut.-Col. T. P., R.A.M.C., India.
*Wutzdorff, Dr., Berlin.

*Yule, Dr. Pratt, Bloemfontein.

*Zuntz, Prof. N., Berlin.

The work of the Committee has closely followed the lines which were indicated in their report of last year. Investigations of three kinds are being undertaken :—

I. The collection of data regarding climate and statistics of disease and death in various parts of the world.

II. The collection of original communications dealing with the health of various localities by competent authors.

III. The production of original researches.

I. The collection of data to be collected under the first heading are :—

(i) Climatological data regarding various places.

(ii) Death statistics in communities where the total number of persons under investigation is known, *e.g.*, in the Army.

(iii) Death statistics over the general population of the district investigated.

For the performance of this task a document has been drawn up giving the necessary instructions, and is being circulated with the forms on which the returns are to be made. It is intended to send these papers to four classes of persons, viz. :—

(*a*) Members of the Sub-Committee, for distribution to observers known to them.

(*b*) Heads of all Government departments who are likely to be able to assist.

(*c*) Medical officers of health.

(*d*) Certain private observers.

The Medical Department of the Navy has undertaken the distribution of these forms to their officers.

II. For the purpose of collecting original papers of value on the health of various localities by competent authors, a list of assessors has been drawn up, who shall report to the Committee on the merits of the original communications as they come to hand.

III. The production of original researches. A commencement has been made in this direction by a preliminary research on the subject of perspiration.

Professor Zuntz has interested himself actively in this portion of the work of the Committee. He is putting at its disposal the results which are being obtained by Drs. Jaffe and Schilling, who are investigating the conditions of metabolism in Togo, German West Africa. It seems probable that an effort will be made to perform researches on the same lines in English and other dependencies under the auspices of the Committee.

It is obvious that if the work of the Committee is to be of any value it must be done with very great care; and therefore they have devoted their whole time and all the money at their disposal to the preparation of forms which will be issued for the collection of statistics. In order that the collections should be comparable, it was necessary to have the forms drawn up with the utmost possible care, and this would have been practically impossible without the constant attendance and active co-operation of the Registrar-General, Sir Wm. C. Dunbar, Bart., C.B., of Dr. J. F. W. Tatham, Superintendent of Statistics, General Register Office; of Dr. W. N. Shaw, F.R.S., Director of the Meteorological Office; and of Lieut.-Col. R. J. S. Simpson, C.M.G., R.A.M.C., to all of whom the Committee are deeply indebted for the labour which they have undertaken. In connection with the drawing-up of the forms for

distribution, the Director-General of the Army Medical Department has interested himself greatly in the work of the Committee, and, being unable to attend himself, deputed Colonel Simpson to act for him. The Director-General of the Navy has deputed Inspector-General May, who has been a constant attendant at the meetings and given valuable help, and has arranged that the forms drawn up by the Committee shall be distributed to medical officers of the Navy all over the world.

The amount of work entailed was more than could be accomplished by the Honorary Secretaries, and it was found necessary to employ a paid Secretary at a rate of 25*l.* a year.

The whole of the grant of 55*l.* has been expended, and the Committee ask that a further grant of 100*l.* be placed at their disposal for the purpose of sending out the forms which have been drawn up dealing with the material that is being collected.

APPENDIX.—*Monthly Return of Diseases.*

The form itself is too large to reproduce. It provides for the following particulars:—

1. Place and period of observation.
2. The total population (male and female separately) among whom the attacks and deaths occurred which are recorded in the form.
3. The number of fresh cases coming under observation during the period and the deaths among them.
4. The age grouping of the attacks or deaths (males and females separately) according to the following system: Under 1 year; from 1 to 25, by five yearly periods; from 25 to 75, by ten-yearly periods. This allows of rearrangement to suit the grouping in the corresponding census.
5. The list of diseases (printed below) is prepared from the 1906 edition of the 'Nomenclature of the Royal College of Physicians and Surgeons,' and space is left to admit of the insertion (in manuscript) of any diseases not included in the printed list.

General Diseases.

3. Blackwater Fever.
4. Beri Beri.
5. Cerebo-spinal fever.—*Syn.*: Epidemic Cerebo-spinal meningitis.
6. Chicken-pox.
7. Cholera.
9. Dengue.
10. Diphtheria.
11. Dysentery—(*a*) Amœbic; (*b*) Bacillary.
12. Infective endocarditis.
13. Enteric fever.—*Syn.*: Typhoid fever.
14. Enteritis infective.—*Syn.*: Epidemic diarrhœa.
15. Erysipelas.
16. Gangrene—acute infective.
18. German measles.
21. Influenza.
22. Kala azar.
23. Leprosy—(*a*) Nodular; (*b*) Anæsthetic.
25. Malaria—(*a*) Tertian; (*b*) Quartan; (*c*) Aestivo-autumnal; (*d*) Chronic. *Syn.*: Malarial cachexia.
26. Measles.
27. Malta fever.—*Syn.*: Mediterranean fever.
28. Mumps.
31. Plague.
32. Pneumonia.—*Var.*: Epidemic pneumonia.
34. Pyrexia—of uncertain origin.
35. Rabies.
36. Relapsing fever.
37. Rheumatic fever.—*Syn.*: Acute or sub-acute rheumatism.
38. Scarlet fever.
40. Sleeping sickness.
41. Small-pox.
42. Syphilis.
43. Tetanus.
44. Tuberculosis (*specify organs primarily affected*).
45. Typhus.

47. Whooping cough.
49. Yellow fever.
50. Alcoholism, including delirium tremens.
61. Anæmia.
62. Anæmia, chronic splenic.
63. Anæmia, pernicious.
64. Chlorosis.
65. Cretinism.
66. Diabetes (mellitus).
67. Exophthalmic goitre.
68. Gout.
69. Hæmophilia.
70. Leucocythæmia.
71. Lymphadenoma.—*Syn.*: Hodgkin's Disease.
72. Myxœdema.
76. Rickets.
77. Scurvy.
80. New growth, malignant. — *Var.*: Cancer.
82. Effects of parasites[1]—(*a*) Bilharzia hæmatobium; (*b*) Ankylostoma duodenale.

Diseases of the Nervous System.

86. Multiple neuritis, special form of.
115 Chorea.
133. Hysteria.
143. Neurasthenia.

Diseases of the Eye.

166(g). Conjunctivitis, granular.
202(a). Retinitis pigmentosa.
214(b). Functional night blindness.—*Syn.*: Nyctalopia.

Diseases of the Ear.

Diseases of the Nose.

285. Hypertrophy of the pharyngeal tonsil—adenoid vegetation.

Diseases of the Circulatory System.

293. V.D.H. (*specify valves affected*).
305. Disordered action of the heart.
316. Aneurism.
324. Phlebitis.

Diseases of the Respiratory System.

337. Hay fever.
338. Asthma,
404. Bronchitis.
413. Broncho-pneumonia.
425. Pleurisy.

Diseases of the Digestive System.

446. Dental caries.
475. Tonsilitis. — (*a*) Follicular; (*b*) Suppurative. (*Quinsy.*)
515. Inflammation of intestines; (2) Appendicitis.
526. Sprue.
568(*a*). Inflammation of the liver.—*Syn.*: Hepatitis. *Var.*: Tropical abscess.
568(*b*). Cirrhosis of liver.—(*a*) Portal (atrophic) cirrhosis; (*b*) Biliary (hypertrophic) cirrhosis.
570. Acute yellow atrophy.

Diseases of the Lymphatic System.

605. Inflammation of lymphatic glands. —*Var.*: Climatic bubo.
615. Filariasis.

Diseases of the Thyroid Body.

638. Goitre.

Diseases of the Supra-renal Capsules.

Diseases of the Urinary System.

687. Calculus and gravel.
691. Diabetes insipidus.

Diseases of the Generative System

Diseases of the Breast.

Diseases of the Organs of Locomotion.

Diseases of the Connective Tissue.

Diseases of the Skin.

962. Eczema.
974. Psoriasis.
998. Oriental sore.—*Syn.*: Delhi boil; Aleppo boil; Biskra button; and other local names.
1009. Prickly heat.
1025. Effects of heat—(*b*) Heat-stroke; (*c*) Sunstroke.
1028. Effects of lightning.

Suicide.[2]

[1] And such others as may be of local importance.

[2] The mode of suicide (drowning, hanging, &c.) should be specified in the column headed "Diseases."

The Structure of Fossil Plants.—Third Interim Report of the Committee, consisting of Dr. D. H. SCOTT (*Chairman*), Professor F. W. OLIVER (*Secretary*), Mr. E. NEWELL ARBER, *and* Professors A. C. SEWARD *and* F. E. WEISS.

THE Committee appointed at the York meeting to investigate the structure of Fossil Plants beg to report that the sum of 2*l*. only has been spent. This has been paid for sections of *Stigmaria* for Professor Weiss's work, still in progress, on the structure and affinities of that genus.

The Committee ask for leave to retain the balance of 3*l*., now in the hands of the Chairman.

Research on South African Cycads, and on Welwitschia.—Interim Report of the Committee, consisting of Professor A. C. SEWARD (*Chairman*), Mr. R. P. GREGORY (*Secretary*), Dr. D. H. SCOTT, *and* Dr. W. H. LANG.

Professor Pearson reports as follows :—

1. *South African Cycads.*

A. Field observations and a study of the life-histories of various species, commenced in 1905, have been continued. A considerable amount of material has yet to be examined before I am able to publish my general results.

B. I have paid particular attention to *Encephalartos Frederici-Guilielmi*, which is one of the most interesting of the South African species.[1] I hope to publish a second paper of field-observations on this species when I have been able to clear up a few points that are still doubtful.

C. During a visit to the habitat of this species in September 1906 I collected a large number of seeds of various ages, from which I have obtained a fairly complete series of stages of the development of the pro-embryo and embryo. A similar study has been made of the pro-embryo and young embryo of *Stangeria sp.* and of the early pro-embryo of *Encephalartos villosus*. I propose to publish an account of this work as soon as I have been able to prepare the drawings.

D. An investigation into the development of the microsporangium and microspores of *Stangeria paradoxa*, referred to in my last report, is still unfinished, as material showing certain missing stages has not yet been obtained.

2. *Welwitschia.*

I visited Damaraland in January of this year, and stayed at Welwitsch (three days) and Haikamchab (seven days), two well-known localities of Welwitschia, the one to the south and the other to the north of the lower Swakop river. I made observations on the relations of the plant to the prevailing life-conditions, and collected and fixed a large number of cones for the completion of the study of its life-history.

[1] *Vide* 'Notes on South African Cycads'—(1) in *Trans. S. A. Phil. Soc.*, xvi. (1906), pp. 342, 343.

A paper entitled 'The Living Welwitschia'[1] contains some of the field observations, and shows that the ovules are insect-pollinated; others are included in a general paper ('Notes on a Journey from Walfisch Bay to Windhuk') which I have sent to the Director of Kew for publication; some will form part of a future paper.

In collaboration with Mr. E. E. Galpin, F.L.S., who accompanied me, I made a study of the flora of the desert area in which Welwitschia grows; the results will be published as soon as we are able to work up our collections.

The cones being in a more advanced condition than those collected a fortnight or three weeks earlier in the season, in 1904, I have obtained material which is expected to yield stages which I was unable to describe in my former paper. At present I have only been able to make a preliminary examination of a few ovules. Nearly all seem to be in an excellent state of preservation, and I have already identified two sperm-cells in the pollen-tube and several stages in the development of the pro-embryo—these, however, I am not yet in a position to describe. I hope to have the results of this work ready for publication by the middle of 1908.

Studies of Marsh Vegetation.—Report of the Committee, consisting of Dr. F. F. BLACKMAN (*Chairman*), Mr. A. G. TANSLEY (*Secretary*), Professor A. C. SEWARD, *and* Mr. A. W. HILL.

THE researches to aid which this Committee was appointed were undertaken by Professor Yapp, primarily with the object of investigating the problem of xerophily in marsh plants. So far the researches have been carried on chiefly in the Fens of Cambridgeshire, where marshes of the 'Flach-moor' type are still to be found, notably at Wicken, where indeed most of the actual work has been done, though other localities have been visited.

The vegetation of Wicken Fen has been studied in some detail, at different seasons of the year, *in situ*; visits for this purpose were made in August, November, March, May, and July.

Particular attention has been paid to the mutual relations of the different plants composing the vegetation and to their modes of growth, vegetative periods, and other peculiarities which, it was thought, might affect the general problem.

A considerable amount of material has been preserved for anatomical investigation.

A series of physical observations has been made of the maximum and minimum temperatures, and also of the evaporating power of the air,[2] at different levels in the vegetation, which in many spots forms a dense tangled mass some 5 feet in height. These observations have only been commenced during the present summer (1907), but it is proposed to continue them for a further period.

In order to test the possible effect of varying conditions of soil, moisture, and light, a large number of plants of *Spiræa Ulmaria* are now

[1] *Nature*, April 4, 1907.

[2] For this purpose an improved form of evaporimeter has been employed, based on the same principle as that described by Livingston, *The Relation of Desert Plants to Soil, Moisture, and to Evaporation.* Washington, 1906.

being grown, both at the Botanic Garden, Cambridge, and also at the University College of Wales, Aberystwyth. This species was selected as it seemed in some respects especially likely to throw light on the problem under investigation.

Experimental Studies in the Physiology of Heredity.—Report of the Committee, consisting of Mr. FRANCIS DARWIN (*Chairman*), Mr. HAROLD WAGER (*Secretary*), Professor J. B. FARMER, *and* Mr. R. P. GREGORY.

THE Committee have adopted as their report the following statement by Mr. Bateson :—

The experiments on heredity undertaken in conjunction with Mr. R. C. Punnett have been continued during the past year. The subjects most used were sweet peas and fowls.

In the case of sweet peas we have chiefly investigated the phenomenon of gametic coupling between certain colours and various structural peculiarities. The results arrived at are too complex for brief description, but we hope to prepare a report on them shortly.

In regard to poultry we have been mainly occupied with questions of colour inheritance. We have succeeded in distinguishing two classes of birds, both having white plumage, which, when crossed together, uniformly produce fully coloured F_1. This colour thus depends on the co-existence of two complementary factors, as in flowers.

The dominant whites, previously described, evidently owe their dominance to the presence of a third and distinct factor. The evidence strongly suggests that any combination of these three factors (or their allelomorphic absences) may exist.

Another principal subject of investigation is the pigmentation of connective tissues in silky fowls and its hereditary transmission. The development of this peculiarity is in some way dependent on sex, and experiments are in progress for elucidating the interrelation between the two phenomena.

Several minor inquiries are also in progress.

It is not proposed to apply for a reappointment of the Committee.

The Peat Moss Deposits in the Cross Fell, Caithness, and Isle of Man Districts.—Report of the Committee, consisting of Professor R. J. HARVEY GIBSON (*Chairman*), Professor R. H. YAPP (*Secretary*), Professor J. REYNOLDS GREEN, *and* Mr. CLEMENT REID. (*Drawn up by* Mr. FRANCIS J. LEWIS.)

THE Committee were appointed with the object of ascertaining, by means of excavations, the succession of plant remains in the extensive area of peat in the basins of the rivers Halladale, Strathy, and Armadale Burn, flowing out to the north coast of Scotland, and on the Cross Fell Range in Cumberland, and to compare these areas with others previously investigated by one of the Committee in various parts of Scotland.[1]

[1] 'Plant Remains in the Scottish Peat Mosses,' Part I., *Trans. Royal Soc. Edin.*, vol. xli.; Part III., No. 28, 'Plant Remains in the Scottish Peat Mosses'; Part II., *Trans. Royal Soc. Edin.*, vol. xlv.; Part II., No. 13.

Work was commenced at the beginning of January 1906 on the Cross Fell area, continued during part of March and April 1906, and finished in April 1907. The time taken by the work in this area is accounted for by the complicated character of the beds and the frequent occurrence of snow and frost, rendering the work of section-cutting unusually tedious.

Field work on the Caithness-Sutherland border was begun and completed during July 1906.

The succession in these two regions will be described first, and afterwards the correlation of the strata with those in other districts will be briefly discussed.

The Caithness-Sutherland Border. (Ordnance Survey Sheets 109, 115.)

One of the most extensive tracts of peat in Scotland is situated in this region. Northward of the Torridonian sandstone hills of Ben Griam Mor and Ben Griam Beg a platform of crystalline schists stretch up to the north coast for a distance of twenty miles, and nearly the whole of this platform is covered with peat over 10 feet in thickness. Sections were taken in the basins of the rivers Halladale, Strathy, and Armadale Burn over ground lying between 400 feet to 800 feet altitude.

The present vegetation of the whole area is one very characteristic of the west and north-west Highlands. The most abundant plant on the moors is *Scirpus cæspitosus*, mixed with much *Rhacomitrium lanuginosum*, *Myrica Gale*, and, in less abundance, *Erica Tetralix*, *Calluna vulgaris*, *Eriophorum vaginatum*, *Drosera longifolia*. The peat is deeply channelled in places, exposing to view one, or more, generally two, forest beds of pine.

The sections taken in the Halladale basin will be described first.

Near the head of Dyke Burn (one of the larger tributaries of the Halladale) is a semicircle of well-preserved moraines. Although the slopes of these are almost free from peat, the hollows between them are covered with peat to the depth of more than 15 feet.

The moraines lie at an elevation of 700 feet and about three-quarters of a mile north of the summit of Ben Griam Beg.

The succession of strata between the moraines and Ben Griam Beg is as follows :—

Characteristic plants.	Accompanying plants.
1. *Scirpus cæspitosus.*	1. *Sphagnum.*
2. *Pinus sylvestris.*	2. *Calluna vulgaris*, *Betula alba.*
3. *Betula nana.*	3. *Salix reticulata*, *Empetrum nigrum.*
4. *Betula alba.*	4. *Calluna vulgaris*, *Empetrum nigrum* (scarce).
5. *Hypnum* sp. and lichens.	5.
6. *Salix reticulata.*	6. *Salix arbuscula*, *Dryas octopetala*, *Hypnum* sp.

Sand and gravel.

Total depth 17 feet.

Considerable difficulty was experienced in cutting many of the sections owing to the numerous large trunks of pine in zone 2. These had to be cut through with axe and saw before the underlying peat could be excavated.

The most noticeable features here are the two beds of forest separated by arctic plants and the arctic plant bed occurring at the base of the whole series.

In the hollows between the moraines the following succession occurs :—

Characteristic plants.	Accompanying plants.
1. *Scirpus cæspitosus.*	1. *Sphagnum.*
2. *Pinus sylvestris* (rather small trees with the trunks lying E. and W.).	2. *Calluna vulgaris.*
3. *Eriophorum vaginatum.*	
4. *Betula alba* (wood rather small, but the bed attains a thickness of 5 feet)	
5. Clay and clayey silt with birch bark remains, 1 foot.	
6. Close layer of large stones mixed with sand and gravel.	

In other places the forest beds rest directly upon morainic material ; but when this is the case the basal layers are always mixed with much sand and gravel, and the peaty material has apparently been rearranged by running water.

Sections taken some miles down Dyke Burn at an elevation of about 400 feet showed the following succession :—

Characteristic plants.	Accompanying plants.
1. *Scirpus cæspitosus.*	1. *Sphagnum*
2. *Pinus sylvestris.*	2. *Calluna vulgaris.*
3. *Eriophorum vaginatum.*	3. *Sphagnum.*
4. *Betula alba.*	4. *Eriophorum vaginatum, Calluna vulgaris.*
5. *Empetrum nigrum.*	5.
6. *Potentilla Comarum.*	6. *Menyanthes trifoliata.*
7. *Carex* sp.	7. *Menyanthes trifoliata, Viola palustris, Equisetum* sp.
8. Sandy peat.	

The basal arctic plants are absent here, but other sections taken on the western edge of the basin near the Garbh-allt (flowing into Dyke Burn) showed the following strata :—

	Characteristic plants.	Accompanying plants.
2 feet.	1. *Scirpus cæspitosus.*	1. *Sphagnum.*
2 feet.	2. *Pinus sylvestris.*	2. *Calluna vulgaris* (abundant).
1½ feet.	3. *Eriophorum vaginatum.*	3. *Calluna vulgaris* (very scarce).
2½ feet.	4. *Betula alba.*	4. Traces of *Eriophorum vaginatum, Calluna vulgaris,* and *Polytrichum commune.*
2 feet.	5. *Salix reticulata.*	5. *Betula nana, Empetrum nigrum, Arctostaphylos alpina.*
	Sand and boulder clay.	

The lower portion of Dyke Burn flows between high banks of peat, and an examination of these showed some points of interest. At some of the sharp bends in the stream a layer of aquatic plants lay below the arctic zone. Such a succession is illustrated in the following section :—

Characteristic plants.	Accompanying plants.
1. *Scirpus cæspitosus.*	1.
2. *Pinus sylvestris.*	2. *Calluna vulgaris.*
3. *Eriophorum vaginatum.*	3. *Sphagnum* and stunted *Calluna vulgaris.*
4. *Betula alba.*	4. *Vaccinium Myrtillus.*
5. *Potentilla Comarum.*	5. *Salix arbuscula, Arctostaphylos alpina, Menyanthes trifoliata.*
6. *Equisetum* sp.	6.
7. *Potamogeton natans: P. Zizii, P. obtusifolius.*	7.

Characteristic plants.	Accompanying plants.
8. Light-coloured tenacious clay mixed with fine sand.	8.
9. Gravel.	9.

The presence of peat formed from aquatic plants below the arctic zone is an interesting feature, and suggests that the summers of that time were fairly warm and long enough to allow these aquatic plants to seed freely. Similar aquatic beds below the basal arctic zone have been found during the examination of the peat in the Cape Wrath District, and in the Shetlands.[1]

Between Allt Bad Eauring and Garbh-allt (two small burns flowing into Dyke Burn) the banks of Dyke Burn are about 3 feet high and formed of peaty sand. Rather below the summer level of the burns occurs a layer of leaves and small twigs mixed with sand. This rests upon water-sorted glacial deposits. This leaf bed is chiefly formed by the leaves of creeping willows—*Salix reticulata, S. arbuscula,* and stems of *Potentilla Comarum.* The material is certainly drift, owing to the thin layers of sand between the leaves, but it does not bear evidence of having been carried far, as the bark on the twigs and the leaves are quite uninjured. In the upper portions of the leaf bed twigs of *Betula alba* are fairly abundant. This bed was traced for about half a mile, and sections dug at intervals all showed the same features, but the bed is thickest and best seen at sharp bends in the stream.

Owing to this bed being only two miles from the summit of Ben Griam Beg (which rises to 1,903 feet) it seemed at first possible that it represented the débris of arctic willows now growing on the summit, but a careful examination of the vegetation on the summit and flanks of the hill showed no trace of any creeping willows. The thickness of the bed and the uninjured condition of the plant remains suggest that they were deposited by a slow stream, and therefore through a fairly lengthy period. The succession amongst the moraines probably indicates the origin of the material forming the leaf bed. The upper zone of forest there is underlaid by a bed of arctic plants resting upon a lower zone of forest, and it seems most probable that the leaf bed was formed during the growth of the intercalated arctic plants.

Sections in the Strathy Basin.—The whole drainage area of the river Strathy (about fifteen miles in length) is covered with an unbroken sheet of deep peat. This was examined at many different points to within five miles of the sea. Northward of this the peat becomes shallow and is interrupted by many outcrops of schist.

The following section shows the general succession met with :—

Characteristic plants.	Accompanying plants.
1. *Scirpus cæspitosus.*	1. *Sphagnum, Eriophorum vaginatum.*
2. *Pinus sylvestris* (trees rather small, but forming a definite layer).	2.
3. *Eriophorum vaginatum.*	3. *Sphagnum.*
4. *Betula alba* (wood generally much decayed, but bark plentiful and well preserved).	4.
5. *Eriophorum vaginatum.*	5. *Menyanthes trifoliata, Potentilla Comarum.*
6. *Salix reticulata.*	6. *Arctostaphylos alpina.*
7. Boulders with intervening spaces packed with coarse sand and grit.	7.

[1] 'The Plant Remains in the Scottish Peat Mosses,' Part III., *Trans. Royal Soc. Edin.*, vol. xlvi. 1907.

The salient features of all the peat lying in this district may be summarised as follows :—

The upper forest consists of two layers—the upper of *Pinus sylvestris* and the lower of *Betula alba.* They are separated by 1–4 feet of peat, which in some places is formed from *Eriophorum* and other peat bog plants, and in others by peat formed from *Betula nana*, *Salix reticulata*, and *S. arbuscula.* This seems to be the usual character of the Upper Forest over large tracts of the Highlands. It has now been found on the Spey-Findhorn Watershed, Findhorn-Nairn Watershed, Coire Bog, Easter Ross, in Assynt, and also near Altnabreac, further east than the present area. So far arctic plants between the two layers of the upper forest have only been found in Assynt, on the Grampians, and in the present area. The absence of any plants in the upper forest indicating colder conditions than prevail over lowland areas at the present day is significant, and suggests that the two layers of forest indicate genial conditions, whilst the intervening peat was accumulated under sub-arctic or arctic conditions. Evidence bearing upon this point has been obtained from Cross Fell and will be described presently. It is evident that the area under consideration exhibits the same sequence as other Highland areas investigated during 1905 and 1906.

Most of the peat began to form under arctic conditions, when a close growth of *Salix reticulata*, *Arctostaphylos alpina*, *Empetrum nigrum*, *Dryas octopetala* and mosses covered the ground.

This vegetation was succeeded by birch forest with *Calluna vulgaris* and *Lychnis diurna.* In some places the birch attained a fair size, but in the Strathy Basin the 'forest' appears to have been formed of very small or shrubby trees. The trees were succeeded by peat bog plants such as *Eriophorum*, *Scirpus cæspitosus*, and *Sphagnum* in some places, and by *Betula nana*, *Salix reticulata*, *S. arbuscula* in others. This sequence is so widespread that it must indicate a general change in climatic conditions at this time. A second forest succeeded the peat bog and arctic vegetation, and this is covered with *Eriophorum*, *Scirpus*, and *Sphagnum* peat persisting to the present day.

The Cross Fell District.

All the peat for several miles round Cross Fell lies at altitudes above 2,000 feet, rising nearly to the summit at 2,930 feet. In depth it varies from 10–15 feet at lower levels to 3–4 feet near its upper boundary.

The only area free from peat is an outcrop of limestone on Rake End, forming the northern boundary of the Tees basin near its head, and a small limestone outcrop forming Bulmans Hills in the basin of the river S. Tyne, to the N.E. of Cross Fell. These outcrops are covered with pasture; elsewhere the peat forms a continuous sheet, covered with *Eriophorum*, *Calluna*, *Vaccinium Myrtillus*, *Rubus Chamæmorus*, and *Empetrum*, or furrowed into deep peat hags quite bare of vegetation.

The peat was examined by means of sections and borings at its upper boundary near the summit of Cross Fell, and in the basins of the Tees and Tyne. The deposits in the basin will be described first.

At about 2,000 feet the general sequence is as follows :—

1. *Sphagnum* peat with *Calluna* and *Empetrum.*
2. *Carex* peat.
3. *Betula alba* with *Alnus glutinosa*, *Lychnis diurna*, *Ajuga reptans*, *Elatine hexandra*, *Ranunculus repens.*

4. Silt.
5. *Salix arbuscula* with *Empetrum nigrum*, *Viola palustris*, *Potentilla Comarum*, *P. tormentilla* (?).
6. *Salix reticulata*, *Arctostaphylos alpina* imbedded in silt and sand, *Alchemilla alpina* (?).
7. Stony clay.

This appears to have been the general history of the vegetation at lower levels in Teesdale, but very frequently the birch zone rests almost directly upon the drift, as the following section at 2,300 feet shows :—

1. *Eriophorum vaginatum* with traces of *Scirpus cæspitosus* and *Calluna*.
2. *Calluna* peat.
3. *Betula alba* with *Vaccinium Myrtillus* and *Ajuga reptans*.
4. Peat formed almost entirely from the rhizomes and leaves of *Phragmites communis*.
5. Stony clay.

Above 2,450 feet the birch zone disappears, and the following strata are found on Baron Hills at 2,500 feet :—

1. Black crumbling peat with no recognisable plant remains.
2. Rhizomes of *Sedum Rhodiola*.
3. *Eriophorum vaginatum*.
4. *Empetrum* peat, formed entirely from stems and seeds.
5. Small creeping Salices, probably *Salix arbuscula*.
6. Stony clay.

The evidence from the whole district points to the existence of one forest bed in the upper layers of peat underlaid by an arctic bed. This corresponds with the succession observed in Caithness shire.

A leaf bed of some interest was found on the banks of the Tees not far from its source. The bank is 5 feet in height, is situated at a sharp bend in the stream, and formed by the following strata :—

1. Peat formed of *Eriophorum*, *Nardus* (?), and *Juncus squarrosus*.
2. *Sphagnum* peat.
3. Stiff blue clay with much slatey débris.
4. Leaf bed.
5. Stones and clay.

The leaf bed begins at about water-level and is 18 inches in thickness, in some places forming part of the bed of the Tees, but covered with stones washed down by the stream. The position of the bed in relation to the stream is much the same as the leaf bed described from the banks of the Dyke River. It extends for only a short distance – not more than 8 feet—and really forms a short band below water-level. As the leaf bed contains the same species as are met with in the arctic bed at the base of the peat, it must belong to that period, the material being washed in by the swirl of the water as it passed round the sharp bend, and from time to time gently covered over with fine sand and clay.

The remains so far obtained from the bed are as follows :—

Salix arbuscula, leaves—very abundant.
S. reticulata, leaves—not frequent.
Viola palustris, seeds.
Potentilla Comarum, achenes.
Carex, spp.

The peat at 2,600–2,900 feet, near the summit, is seldom more than a few feet in thickness, and forms detached banks and mounds. It has been so split up by the action of frost that the plant remains can seldom be

determined. The forest zone is absent and *Empetrum*, *Eriophorum*, and *Sphagnum* appear to be the principal plants. The summit plateau at 2,930 feet is covered with patches of *Rhacomitrium lanuginosum* alternating with bare stony areas.

The Tyne Basin.—Sections were taken over the great expanse of peat on each side of Smittergill Burn, Black Burn, and Cash Burn, forming the headwaters of the river S. Tyne, on the north side of Cross Fell.

In most places the remains of an arctic or sub-arctic vegetation rest upon the drifts : this is covered with a considerable thickness of peat formed from *Phragmites communis*. Above this the birch zone forms a datum line over the whole district. The wood varies greatly in size, but is seldom less than 8 inches and sometimes attains 18 inches in diameter. Where denudation has not been active the forest is overlaid by 7–10 feet of recent peat, but in many places the whole of this has wasted away, leaving the birch wood scattered over the surface of the peat. The presence of *Elatine hexandra* in the forest bed in several sections at 2,000–2,600 feet both in Teesdale and Tynedale is of interest, as this plant is chiefly confined to the western portion of Britain at the present time, and is not typical of peat bogs at high elevations. Of similar interest is the occurrence of *Viburnum opulus* in the birch zone from a section at about 2,330 feet. The presence of these plants implies different conditions from those indicated by the underlying *Salix reticulata* and *S. arbuscula*.

The basal arctic vegetation and the forest bed can be regarded as true horizons, and as they are present both on the Pennines and in Scotland a brief comparison may be made between the two regions :—

General sequence of Strata in the Scottish Highlands.	Sequence of Strata in Teesdale and Tynedale.
1. Recent peat, *Scirpus cæspitosus*, *Sphagnum*, and *Eriophorum*.	Recent peat, *Eriophorum*, *Sphagnum*, and *Calluna*.
2. *Pinus sylvestris* and *Calluna*.	*Betula alba*, *Alnus glutinosa*, *Viburnum opulus*, *Elatine hexandra*, *Lychnis diurna*.
3. *Sphagnum*, *Scirpus cæspitosus*.	
4. *Pinus sylvestris* and *Calluna*.	
5. *Sphagnum* and *Eriophorum*.	*Phragmites communis*.
6. Sub-arctic beds, *Salix arbuscula*, *Empetrum*, and *Potentilla Comarum*.	*Salix arbuscula*, *Empetrum*.
7. *Salix reticulata*, *S. herbacea*, *Dryas octopetala*, *Arctostaphylos alpina*, *Salix reticulata*, &c.	

Whilst the salient features are the same in both regions (*i.e.*, an arctic bed at the base overlaid by a forest bed) nothing can be more striking than the difference in the flora. All the Scottish peat areas, at altitudes approaching 2,000 feet, contain the remains of a moorland flora above or below the forest zone, but in this district, at nearly 2,700 feet, several feet of peat below the forest bed are formed entirely of *Phragmites communis*. The difference is just as marked if we compare the *Phragmites* zone with the present vegetation of *Calluna*, *Vaccinium Myrtillus*, *Empetrum*, *Eriophorum*, and *Rubus Chamæmorus*. Before the period of the Upper Forest, the whole area—even near the summit of Cross Fell—consisted of an extensive reed swamp, and in some places this persisted through the upper forest period. This was the case on the floors of the valleys and at the base of some of the steep escarpments. Several such old swamps or shallow lakes have been traced—one on Cross Gill Pants, where the drifts appear to form a shallow basin, although this has now been filled

with peat. Another similar basin has been found in Tynedale, near Bulmans Hills, at 2,000 feet. In most places, however, the *Phragmites* disappears at the beginning of the Upper Forest period.

The flora of the Upper Forest is also very different from the corresponding zone in the Highlands.

In Scotland this layer nearly always consists of *Pinus sylvestris* and *Calluna*, whilst on Cross Fell it contains *Betula alba*, *Alnus glutinosa*, *Elatine hexandra*, *Viburnum opulus*, *Ajuga reptans*, and *Lychnis diurna*. The last-named plant is very abundant, scores of seeds being obtainable from quite small pieces of peat. The abundance of these plants at comparatively high elevations indicates that the climatic conditions during their growth were much more genial than during the deposition of the *Salix reticulata* and *S. arbuscula* of the basal layers of the peat, and affords some evidence that the forest periods were temperate in character. The stratification of the Upper Forest is different in this area from that in the Scottish Highland areas so far investigated. In place of the two zones of *Pinus sylvestris* separated by peat bog and arctic plants characteristic of the north of Scotland, we have here only a single birch zone. This sequence corresponds with that in the Scottish Southern Uplands. As far as the evidence at present available goes, the Upper Forest period was interrupted by a change which caused a replacement of pine and heather by peat bog and arctic plants. Subsequently the peat areas were re-invaded by a pine and heather association. The changes which produced this alternation in the flora did not apparently extend further south than the north of Scotland, or the Mid-Highlands. The results may be briefly summarised as follows :—

The Caithness-Sutherland area exhibits the same general sequence as other areas in the north of Scotland. The arctic plants found between the two layers of the upper forest is a feature of some importance. The constant alternation of pine forest, *Sphagnum* and *Scirpus* peat free from tree remains, covered with a second pine forest, seemed to indicate a widespread climatic change, and the frequent presence in this district of *Salix arbuscula* and *S. reticulata* in the intervening peat is fairly conclusive.

The Cross Fell area is of interest, as it shows the same stages as areas in the north of Scotland, although the flora is of an entirely different character. The presence of such plants as *Elatine hexandra*, *Ajuga reptans*, *Viburnum opulus*, birch and hazel trees of large size at altitudes of 2,400 feet, points to the fact that the upper forest grew under conditions more temperate than those of the present day. The basal arctic bed, on the other hand, containing *Salix reticulata*, *S. arbuscula*, and *Arctostaphylos alpina*, points to a period when the arctic-alpine plants now confined to small areas in the north of Scotland had a much more extensive range on the hills in the north of England.

Botanical Photographs.—Report of the Committee, consisting of Professor F. W. OLIVER (*Chairman*), Professor F. E. WEISS (*Secretary*), Dr. W. G. SMITH, Mr. A. G. TANSLEY, Dr. T. W. WOODHEAD, *and* Professor R. H. YAPP, *for the Registration of Negatives of Photographs of Botanical Interest.* (*Drawn up by the Secretary.*)

THE Committee have met twice during the past year, and have made arrangements with the British Botanical Survey Committee whereby

photographs dealing with British vegetation will be collected and registered by the Survey Committee, while photographs not falling into that category will be dealt with by the Secretary of the Committee appointed by Section K.

It was decided to house the photographs for the time being at University College, London, Professor F. W. Oliver having kindly undertaken to provide accommodation for the same.

It was also decided to obtain as far as possible a duplicate set of prints, one of which could be sent to persons out of London who are desirous of consulting the collection. The duplicate set will be in the custody of the Survey Committee, and its headquarters will be Cambridge.

The number of photographs added this year is not large, but includes some very interesting ones of Cycads from South Africa taken by Professor H. W. W. Pearson, of Cape Town, and others illustrating the flora of South Africa taken by Professor R. H. Yapp and Professor F. E. Weiss.

The second list of the photographs so far collected is issued together with the present report.

The whole of the grant (5*l.*) made to the Committee has been expended.

List II. of Photographs of Botanical Interest.

Photographed by R. WELCH, 49 *Lonsdale Street, Belfast.* (8 × 6.)

Regd. No.	Local No.	Locality	Subject
277	R.W. 1832	Crom Castle, Upper Lough Erne	'Pleached' yew-tree bower.

Photographed by H. RICHARDSON, 12 *St. Mary's, York.* (1/4.)

Regd. No.	Local No.	Locality	Subject
278	1	Guimar, Teneriffe . .	Lava of 1705, Lichen-covered; January-April 1905.
279	2	Teneriffe	*Euphorbia Regis Jubæ* in Malpais; 1905.
280	3	„	*E. canariensis*; January-April 1905.
281	4	„	*E. canariensis*, Chrysanthemum in foreground; January-April 1905.
282	5	„	*E. canariensis* in flower; January-April 1905.
283	6	„	*E. canariensis* associated with *E. Regis Jubæ*, *Senecio Kleinii*, and Opuntia; typical association of the Malpais or lava wilderness at low level; January-April 1905.
284	7	Near Tacaronte, Teneriffe .	Canary Palm; January-April 1905.
285	8	Puerto Oratava, Teneriffe .	Canary Palm with leaves trimmed; January-April 1905.
286	9	Teneriffe	*Dracæna draco* (young tree); seeds forming.
287	10	Puerto Oratava, Teneriffe .	Eucalyptus and Aloe (planted) at entrance to Grand Hotel; January-April 1905.
288	11	Near Puerto Oratava, Teneriffe	Banana; January-April 1905.
289	12	Guimar, Teneriffe . .	Opuntia in foreground, Figs behind; stony but cultivated ground.

Regd. No.	Local No.	Locality	Subject
290	13	Teneriffe	*Opuntia Dillennii*, Mesembryanthemum in foreground; close to seashore.
291	14	Agua Manza, Teneriffe .	Chestnut, upper limit of cultivated land; January-April 1905.
292	15	Near Tacaronte, Teneriffe .	Laurel forest; January-April 1905.
293	16	" " "	Monte Verde.
294	17	Teneriffe	Monte Verde, *Cytisus* sp. (white flowers); January-April 1905.
295	18	Near Tacaronte, Teneriffe .	Monte Verde, Erica, &c.
296	19	" " "	*Erica arborea*; January-April 1905.
297	20	" " "	*Pinus canariensis*; January-April 1905.
298	21	Teneriffe	Retama at Pedro Gil; January-April 1905.
299	22	"	Retama and snowdrift at Pedro Gil.
300	23	"	Retama and Peak from Pedro Gil; January-April 1905.
301	24	"	Retama above clouds at Pedro Gil, *Spartium supra nubium*; January-April 1905.

Photographed by Alemana, *Teneriffe.* $(6\frac{1}{4} \times 8\frac{1}{2}.)$

302	—	Teneriffe	*Euphorbia canariensis.*

Photographed by M. Baeze, *Teneriffe.* $(6\frac{1}{4} \times 8\frac{1}{2}.)$

303	63 ?	Teneriffe . . .	*Dracæna draco.*

Photographed by R. Welch, 49 *Lonsdale Street, Belfast.* $(8 \times 6.)$

304	R.W. 19	Sperrin ? Mts., Co. Derry .	*Spiranthes Romanzoffiasa*; whole plants with six spikes of flowers.
305	26	Belfast	*Chærophyllum temulum*; in natural habitat.
306	2	Howth Cliffs, Ireland .	*Inula crithmoides* (Golden Samphire); growing on cliffs.
307	27	Near Cloonee, Kenmare, Kerry	*Cotyledon umbilicus*; 24 inches high.
308	29	The Tunnels, Kenmare, Kerry	*Saxifraga geum* and *S. umbrosa*; one plant, *S. umbrosa*, in centre surrounded by numerous plants of *S. geum*.
309	16	Kenmare, Kerry . .	*Euphorbia hiberna*; in the woods.
310	71	Co. Tyrone	*Galium palustre*; growing on a bog.
311	48	Boyne Valley, Ireland .	*Rosa arvensis*; in hedgerow.
312	32	Killarney, Ireland . .	*Arbutus unedo*; part of grove.
313	25	Banagher Glens, Ireland .	*Hypnum undulatum* and *Thuidium tamariscinum*; in natural habitat.
314	7	Kilcoole, Wicklow, Ireland	*Eryngium maritimum*; growing on shore.
315	×21	Bundoran, Ireland . .	*Lithothamnium*—3 species encrusting *Patella vulgata* (central mass is coralline only). Pools.

Photographed by G. K. Ballance, *St. Moritz Dorf, Switzerland.*

316	1536	Switzerland	*Gentiana purpurea*; upper part of flowering plants.
317	1532	"	*Anemone sulphurea*; whole plants bearing fruits.
318	1531	"	*Sedum album*; in natural habitat.
319	1539	"	*Petrocallis pyrenaica*; in natural habitat.

Regd. No.	Local No.	Locality	Subject
320		Switzerland	*Sempervivum montanum*; in natural habitat.
321	20C	,, ...	*Gnaphalium Leontopodium*; in natural habitat.
322	18C	,, ...	*Rosa canina*; two flowers and foliage against a dark background.
323	86D	,, ...	*Anemone nemorosa*; in flower growing under trees.
324	1528	,, ...	*Androsace helvetica* (in flower); natural habitat.
325	1245	,, ...	*Primula auricula* (in flower); natural habitat.
326	1241	,, ...	*Dryas octopetala* (in flower); in natural habitat.
327	1542	,, ...	*Saxifraga oppositifolia*; a patch of plants in flower.
328	43D	,, ...	*Crocus vernus*; in field (flowering).

Photographed by R. WELCH, 49 *Lonsdale Street, Belfast.* (6 × 8.)

329	46	The Boyne, Navan, Ireland,	*Alisma plantago*; a clump of plants growing at edge of river; trees in the background.

Photographed by G. K. BALLANCE, *St. Moritz Dorf, Switzerland.*

330	1244	Switzerland	*Globularia nudicaulis*; a clump of plants flowering; in natural habitat.
331	1243	,, ...	*Primula villosa*; a clump of plants flowering; in natural habitat.
332	1526	,, ...	*Campanula* sp. (pale blue); a group of plants with five open flowers growing on stony ground.
333	1533	,, ...	*Cerastium alpinum* and *Saxifraga* sp. growing amongst rocks.

Photographed by F. H. GRAVELY, 5 *Silver Street, Wellingboro'.* (1/4.)

Regd. No.	Locality	Subject
334	Moors above Jacob's Ladder, Edale, Derbyshire	*Rubus chamæmorus*; flower and foliage, in natural habitat; June 1906
335	Near source of the Ashop, Derbyshire	*Rubus chamæmorus*; general view of a patch of the plant in flower; June 16, 1906.
336	Near the Mines, Ulleswater . .	*Lycopodium selago*; plant with bulbils and sporangia in natural surroundings.
337	,, ,, ,, .	*Lycopodium alpinum*, in natural surroundings; June 7, 1906.
338	,, ,, ,, . .	*Lycopodium clavatum*, in natural surroundings; June 7, 1906.
339	,, ,, ,, . .	*Botrychium lunaria* (with fructification), in natural surroundings; June 7, 1906.
340	Woods by Aira Force, Ulleswater .	*Polypodium Phegopteris*, in natural surroundings; June 7, 1906.

Photographed by H. W. W. PEARSON, *S. African College, Cape Town.* (1/2.)

341	E. London, S. Africa	*Stangeria* sp. Plant with male cone, in natural surroundings; May 1906.
342	,, ,, ,, . .	*Stangeria*, in natural surroundings, with *Royena pubescens* in background; May 1906.

Regd. No.	Locality	Subject
343	Nahoonk „	*Encephalartos altensteinii*, in natural habitat; May 1906.
344	Nahom River, E. London, S. Africa	*Encephalartos altensteinii*, in natural habitat; May 1906.
345	Queenstown, S. Africa	*Encephalartos Friderici-Guilielmio*, ♀ in natural habitat; May 1906.
346	Nahoonk, E. London, S. Africa .	*Encephalartos altensteinii*, in natural habitat; May 1906.
347	Nr. Finchaus Nek, Queenstown, S. Africa	*Erythrina acanthocarpa* with *Acacia horrida* scrub in the distance; May 1906.

The Conditions of Health Essential to the carrying on of the Work of Instruction in Schools.—Report of the Committee, consisting of Professor SHERRINGTON (*Chairman*), Mr. E. WHITE WALLIS (*Secretary*), Sir EDWARD BRABROOK, Dr. C. W. KIMMINS, Professor L. C. MIALL, Miss A. J. COOPER, *and* Dr. ETHEL WILLIAMS.

THE Committee have under consideration several matters affecting health in schools, but with regard to some of these the investigations are not sufficiently complete to report progress. They submit, however, a further report on children's playtime and leisure, and an interim statement with regard to ventilation of schools.

The Committee had in co-operation with them in their investigations and deliberations the valuable assistance of Dr. C. Childs, Dr. Friedeberger, Mrs. Gomme, Mrs. Kimmins, Dr. James Kerr, Miss Ravenhill, Dr. C. E. Shelly, Professor W. N. Shaw, Mr. J. Osborne Smith, and Mrs. White Wallis.

Children's Playtime and Leisure.

Following up the previous inquiry on the playtime and leisure of school children, investigations have been made in the neighbourhoods of Bermondsey, Kensington, and Hampstead as to how the playtime allotted to children is spent, and as to how their leisure is employed at home. It is found that there is practically no connection maintained between the school and the home life of the children; therefore that in most cases much of the good done at school is being lost to the children because of the ignorance or indifference of the homes as to the welfare of the children; while in other cases help is being lost that might be rendered to the school by consultation with the parents about the activities of their children at home.

The Committee therefore recommend :—

1. That opportunities be afforded to teachers of meeting the parents of children, in the school building, for talks on school and home matters, with the view of bringing home and school into closer touch; and that for this purpose each class teacher be encouraged to invite the parents of the children in his or her class, once a term if possible, at the end of the afternoon school, in order to interest them in the work done by their own children in school, and to demonstrate to the parents how the physical and moral development of the children has been helped by means of organised play.

2. That teachers be encouraged to include among physical exercises children's singing games and the old English Morris dances.

3. That finding how small an amount of time in school is at present reserved to small children for recreation, the Committee urge that the learning to read and write be delayed for twelve months, and the time thus set free be devoted to playing and resting in a room free from form and desk furniture, and having a lavatory adjoining it.

4. That education authorities be asked to allow the playing of games, other than cricket and football, in spaces already allotted in parks for games; and also to provide such spaces where not provided at present, in order that the voluntary helpers may have opportunities for teaching games to girls and small children.

Ventilation of School Buildings.

At the instigation of the Committee, a series of observations have been carried out during the last year on the relation of symptoms of mental fatigue in school children, whilst at work, to different conditions of ventilation. The results promise to be very instructive. The observations, however, require a long period of time, and are not yet complete.

Moreover, further observations are required on the movements of air-currents in occupied rooms, and on the complicated problems involved in the provision of pure air equally distributed to each occupant of a room, before authoritative statements can be made on this subject.

The Committee desire to be reappointed, and ask to be allowed to use the unexpended portion of the grant made in 1906, for the hire of instruments for investigations in hearing tests for school use.

Curricula of Secondary Schools.—Report of the Committee, consisting of Sir OLIVER LODGE (*Chairman*), Mr. C. M. STUART (*Secretary*), Mr. T. E. PAGE, Professors M. E. SADLER, H. E. ARMSTRONG, *and* J. PERRY, Sir PHILIP MAGNUS, Principal GRIFFITHS, Dr. H. B. GRAY, Professor H. A. MIERS, Mr. A. E. SHIPLEY, Professor J. J. FINDLAY, *and* Sir WILLIAM HUGGINS, *appointed to consider and to advise as to the Curricula of Secondary Schools; in the first instance, the Curricula of Boys' Schools.*

THE Committee submit for consideration the following conclusions which they have reached as the result of their debates :—

1. There is need for secondary schools of different types, with different curricula or combinations of curricula : because

(*a*) All boys are not suited to the same course of study.

(*b*) The requirements of the various callings upon which the boys will subsequently enter differ considerably.

(*c*) The needs of the schools differ in a considerable degree according to the economic conditions of the districts in which they are situated.

Broadly speaking, however, the secondary schools fall into two different types—viz., those in which the majority of boys remain till eighteen or nineteen, and then continue their education at places of

university rank; and those in which the majority leave at fifteen or sixteen and proceed to business. There is, however, no sharp line of demarcation between the two.

2. The Committee consider that one modern foreign language should in all cases be begun at an early age; but are of opinion that it would be a wise educational experiment to postpone the *systematic* teaching of Latin as an ordinary school subject till twelve years of age, and that such a change will prove sufficiently successful to warrant its adoption.

On the other hand, they are of opinion that such absence of *systematic* teaching by no means precludes its *incidental* teaching before the age of twelve by such means as will naturally occur to a fully qualified teacher of young boys.

The Committee also desire to record their opinion that the continued teaching of either of the two dead languages to boys who after serious trial have shown little or no progress in, or capacity for, such linguistic study has little or no educational value; and that, though the mental training afforded by such study is of great value in the case of many boys, yet in the case of others such study not only produces no good results, but does positive harm to their mental and moral progress by reason of their incapacity to grapple with its difficulties.

The Committee go further, and express their doubt whether the authorities in some secondary schools have sufficiently recognised this fact or have provided sufficient alternatives to such linguistic study.

3. The Committee deprecate any form of early specialisation in the education of children, and therefore regard with grave concern the fact that the entrance examinations at the great English public schools give undue prominence to the study of Latin (and Greek) in the course of education at the preparatory schools, the result being that too little time is available for (*a*) the teaching of the mother-tongue, (*b*) manual training, (*c*) science and mathematics.

4. The Committee would deprecate anything like State-imposed rigidity in the organisation and studies of secondary schools.

But the Committee are led to the conclusion that up to twelve years of age there might be a broad general course of education for all. It would in all cases include careful preliminary training in the use of the mother-tongue, so that it could be used in speaking and writing correctly on ordinary occasions, and would further comprise the following divisions:—

(1) Literary. (2) Mathematical. (3) Scientific. (4) Manual Training.

They consider that a school week of twenty-six hours might be divided as follows:—

Literary work, thirteen hours; mathematical and scientific work, nine hours; drawing and manual training, four hours; while for those who after twelve years of age commence the study of Latin the division of time should be: Literary work, sixteen hours; other subjects, ten hours.

5. The Committee are of opinion that the curriculum in secondary schools suffers gravely from the number of subjects which have been crowded into it, and they regard this as the most serious factor in

secondary education at the present time. They are of opinion that this 'overcrowding' is due to two causes :—

(1) The disproportionate amount of time bestowed in many schools on the two ancient languages, which leaves only a small residuum for each of the other subjects now increasingly regarded as essential items of education, the result being that the pupil obtains only a smattering of the knowledge of such subjects.

(2) The ill-founded belief that the curriculum should be an abstract of all modern knowledge.

6. The Committee desire to see a great simplification in the arrangement of examinations for secondary schools, and they strongly recommend that examination and teaching should go hand in hand, the examiners co-operating with the teachers and acting in conjunction with them in order to further the interests of real education.

The Committee would urge upon the universities and professions to accept as qualifying for entrance the leaving certificates granted by each university to the schools which submit to its inspection.

The aim should be to examine in accordance with the teaching, and to pay special attention to the special peculiarity of each school, or group of schools ; and it would be a great relief, and at once improve the teaching of the higher forms, if the results of such examination were accepted by universities and professional bodies without further entrance test.

The Committee particularly deprecate any uniform or centrally administered examination applied to all the schools of the country. For a uniform State examination, if it were made the door of entrance to all higher courses of study and to the professions and Civil Service, would do much evil, focussing the efforts of teachers and pupils upon those parts of the school curriculum in which alone examination is possible. Further, the rivalry between schools would cause the standard of attainment steadily to rise, until the over-pressure became serious and intellectual vigour and independent thought were killed.

7. The Committee feel that no scheme of secondary education can be satisfactory unless it is carried out by teachers of learning and force of character, and they would urge that every effort should be made, by conditions of appointment, by scale of salaries, and by retiring allowances, to attract a high class to the teaching profession, which should be regarded as a very laborious, but very honourable, form of public service. Prompt action in this matter is urgent and imperative ; for, unless something is done without delay, the best interests of the schools, and especially of boys' day-schools, will be sacrificed to a false and disastrous economy.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—Professor A. E. H. Love, M.A., D.Sc., F.R.S

THURSDAY, AUGUST 1.

The President delivered the following Address:—

I propose to use the opportunity afforded by this Address to explain a dynamical theory of the shape of the earth, or, in other words, of the origin of continents and oceans.

The theory which has for more than a century been associated with the phrase 'the figure of the earth' is the theory of the shape of the surface of the ocean. Apart from waves and currents, this surface is determined by the condition that there is no up and down upon it. This condition does not mean that the surface is everywhere at the same distance from the centre of the earth, or even that it is everywhere convex, but that a body moving upon it neither rises against, nor falls in the direction of, gravity (modified by the rotation). A surface which has this character is called an equipotential surface, and the surface of the ocean coincides with part of an equipotential surface under gravity modified by the rotation. This particular equipotential surface runs underground beneath the continents. It is named the 'geoid.' The height of a place above sea-level means its height above the geoid. If we knew the distribution of density of the matter within the earth it would be a mathematical problem to determine the form of the geoid. As we do not know this distribution we have recourse to an indirect means of investigation, and the chief instrument of research is the pendulum. The time of vibration of a pendulum varies with the place where it is swung, and from the observed times we deduce the values of gravity at the various places, and it was shown many years ago by Stokes that the shape of the geoid can be inferred from the variation of gravity over the surface.

The question to which I wish to invite your attention is a different one. If the ocean could be dried up, the earth would still have a shape. What shape would it be? Why should the earth have that shape rather than some other? In order to describe the shape we may imagine that we try to make a model of it. If we could begin with a model of the geoid we should have to attach additional material over the parts representing land and to remove some material over the parts representing sea. Our model would have to be as big as a battleship if the elevations and depressions were to be as much as three or four inches. In thinking out the construction of such a model we could not fail to be impressed by certain general features of the distribution of continent and ocean, and we may examine a map to discover such features. Fig. 1 is a rough map of the world drawn in such a way that to every degree of latitude or of longitude there corresponds the same distance on the map. Certain very prominent features have often been

remarked: the tapering of America and Africa towards the south, the disproportion between the land areas of the northern and southern hemispheres, the excess of the oceanic area above the continental area, which occupies but little more than one-quarter of the surface; the wide extent of the Pacific Ocean, which with the adjoining parts of the Southern Ocean covers nearly two-fifths of the surface. Another prominent feature is the antipodal position of continent and ocean. South America south of an irregular line which runs from a point near Lake

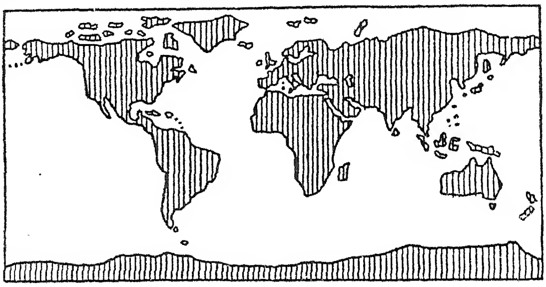


Fig. I.

Titicaca to Buenos Ayres is antipodal to a portion of Asia which lies in an irregular triangle with corners near Bangkok, Kiaochau, and Lake Baikal; but no other considerable parts of the continental system have continental antipodes. The Antarctic continent is antipodal to the Arctic Ocean, Australia is antipodal to the central Atlantic, and so on. Another notable feature is the skew position of South America to the east of North America; South America lies to the east of the meridian 85° west of Greenwich; most of North America lies to the west of it. But although we may observe prominent general features of the distribution, we should find it far from easy to attribute to the form of our imaginary model anything that could be called a regular geometrical figure. When we begin to think about the removal of material from the parts of the model which are to represent oceans and seas, we require a map which gives information about the depth of the sea in different places. Around all the coasts there is a margin of not very deep water. If some part of the sea could be dried up, so that more land was exposed around all the coasts, the area of the surface of the sea would

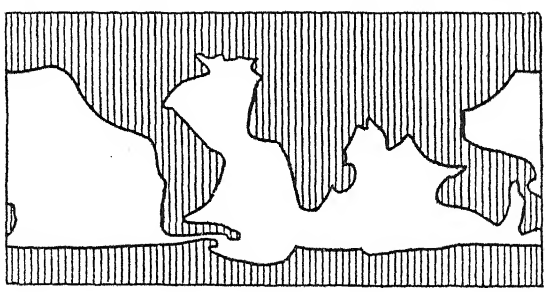


Fig. 2.

be diminished; and it is known that the depth of water that would have to be removed in order to make the area of the sea just half the total area, is about 1,400 fathoms. The contour-line at this depth would divide the surface into two regions of approximately equal area—the continental region and the oceanic region. Fig. 2 represents the contour-line at 1,400 fathoms, or the line of separation of the continental and oceanic regions. The continental region is shaded. In drawing this map I have omitted a number of small islands, and I have also omitted a few

enclosed patches of deep water. Two of these are in the Mediterranean, one in the Arctic Ocean, and others are in the Gulf of Mexico and the Caribbean Sea. The Red Sea, the Mediterranean, and the Arctic Ocean belong to the continental region, and so do the Gulf of Mexico and the Caribbean Sea. At this depth Asia and North America are joined across Behring's Strait, and Europe is joined to North America across the British Isles, Iceland, and Greenland; Australia is joined to Asia through Borneo and New Guinea, and the Australasian continental region nearly reaches the Antarctic region by way of New Zealand. At this depth also South America does not taper to the south, but spreads out, and is separated from the Antarctic region by a very narrow channel. By going down to great depths our problem is very much simplified. We find that the surface of the earth can be divided into continental and oceanic regions of approximately equal area by a curve which approaches a regular geometrical shape. By smoothing away the irregularities we obtain the curve shown in fig. 3, which exhibits the surface as divided up into a continuous continental region and two oceanic regions—the basin of the Pacific Ocean and the basin of the Atlantic and Indian Oceans. We may take our problem to be this: to account on dynamical grounds for the

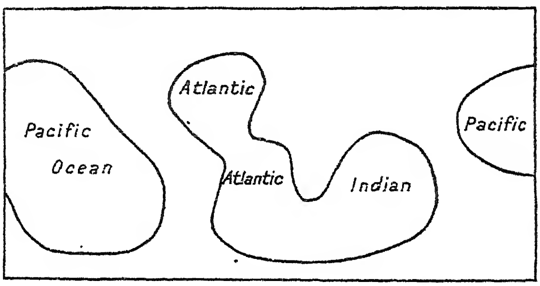


Fig.3.

separation of the surface into a continental region and two oceanic regions which are approximately of this shape.

The key of the problem was put into our hands four years ago by Jeans in his theory of gravitational instability. If there are any differences of density in different parts of a gravitating body, the denser parts attract with a greater force than the rarer parts, and thus more and more of the mass tends to be drawn towards the parts where the density is in excess, and away from the parts where it is in defect. In every gravitating system there is a tendency to instability. In a body of planetary dimensions this tendency, if it were not checked, would result in a concentration of the mass either towards the centre or towards some other part. But concentration of the mass means compression of the material, and it cannot proceed very far without being checked by the resistance which the material offers to compression. There ensues a sort of competition between two agencies: gravitation, making for instability, and the elastic resistance to compression, making for stability. Such competing agencies are familiar in other questions concerning the stability of deformable bodies. A long thin bar set up on end tends to bend under its own weight. A steel knitting-needle a foot long can stand up; a piece of thin paper of the same length would bend over. In order that a body may be stable in an assigned configuration there must be some relation between the forces which make for instability, the size of the body, and the resistance which it offers to changes of size and shape. In the case of a gravitating planet we may inquire how small its resistance to compression must be in order that it may be unstable, and, further, in respect of what types of displacement the instability would manifest itself. If we assign the constitution of the planet, the inquiry becomes a definite mathematical problem. The greatest difficulty in the problem arises from the enormous stresses which are developed within such a body as the earth by the mutual gravitation of

its parts. The earth is in a state which is described technically as a state of 'initial stress.' In the ordinary theory of the mechanics of deformable bodies a body is taken to be strained or deformed when there is any stress in it, and the strain is taken to be proportional to the stress. This method amounts to measuring the strain or deformation from an ideal state of zero stress. If the ideal state is unattainable without rupture or permanent set or overstrain, the body is in a state of initial stress. The commonest example is a golf-ball made of indiarubber tightly wound at a high tension. Now the problem of gravitational instability can be solved for a planet of the size of the earth on the suppositions that the density is uniform and the initial stress is hydrostatic pressure. If the resistance to compression is sufficiently small the body is unstable, both as regards concentration of mass towards the centre and as regards displacements by which the density is increased in one hemisphere and diminished in the other. A planetary body of sufficiently small resistance to compression could not exist in the form of a homogeneous sphere. It could exist in a state in which the surface is very nearly spherical, and the mass is arranged in a continuous series of nearly spherical thin sheets, each of constant density; but these sheets would not be concentric. They would be crowded together towards one side and spaced out on the opposite side somewhat in the manner shown in fig. 4. The effect would be a displacement of the centre of gravity away from the centre of figure towards the side where the sheets are crowded together. How small must the resistance to compression be in order that this state may be assumed

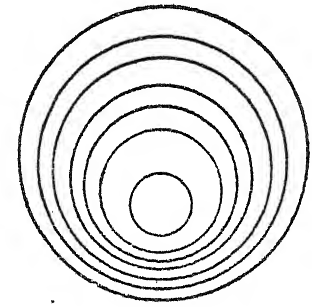


Fig. 4.

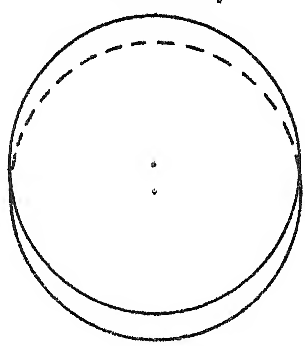


Fig. 5.

by the body instead of a homogeneous state? The answer is that, if the body has the same size and mass as the earth, the material must be as compressible as granite. Granite, as we know it at the earth's surface, is not a typically compressible material. A cube of granite 10 feet every way could be compressed from its volume of 1,000 cubic feet to a volume of 999 cubic feet by pressure applied to every part of its surface; but according to the recent measurements of Adams and Coker the pressure would have to be rather more than two tons per square inch. A homogeneous sphere of the same size and mass as the earth, made of a material as nearly incompressible as granite, could not exist; it would be gravitationally unstable. The body would take up some such state of aggregation as that illustrated in fig. 4, and its centre of gravity would have an eccentric position.

Now how would an ocean rest on a gravitating sphere of which the centre of gravity does not coincide with the centre of figure? Its surface would be a sphere with its centre at the centre of gravity (fig. 5). The oceanic region would be on one side of the sphere and the continental region on the other side. It was pointed out many years ago by Pratt that the existence of the Pacific Ocean shows that the centre of gravity of the earth does not coincide with the centre of figure. There is no necessity to invoke some great catastrophe to account for the existence of the Pacific Ocean, or to think of it as a kind of pit or scar on the surface of the earth. The Pacific Ocean resembles nothing so much as a drop of water adhering to a greasy shot. The force that keeps the drop in position is surface tension.

The force that keeps the Pacific Ocean on one side of the earth is gravity, directed more towards the centre of gravity than the centre of figure. An adequate cause for the eccentric position of the centre of gravity is found in the necessary state of aggregation which the earth must have had if at one time it was as compressible as granite. The theory of gravitational instability accounts for the existence of the Pacific Ocean.

But we can go much further than this in the direction of accounting for t continental and oceanic regions. We keep in mind the eccentric position of the centre of gravity, and try to discover the effect of rotation upon a planet of which the centre of gravity does not coincide with the centre of figure. The shape of a rotating planet must be nearly an oblate spheroid; but the figure of the ocean would, owing to its greater mobility, be rather more protuberant at the equator than the figure of the planet on which it rests. The primary effect of the rotation of the earth upon the distribution of continent and ocean is to draw the ocean towards the equator, so as to tend to expose the arctic and antarctic regions. We have seen that both arctic and antarctic are parts of the continental region. But there is an important secondary effect. Under the influence of the rotation the parts of greater density tend to recede further from the axis than the parts of less density. If the density is greater in one hemispheroid than in the other, so that the position of the centre of gravity is eccentric, the effect must be to produce a sort of furrowed surface; and the amount of elevation and depression so produced can be described by an exact mathematical formula. It has been proved that this formula is the sort of expression which mathematicians name a spherical harmonic of the third degree.

The shape of the earth is also influenced by another circumstance. We know that at one time the moon was much nearer to the earth than it is now, and that the two bodies once rotated about their common centre of gravity almost as a single rigid system. The month was nearly as short as the day, and the moon was nearly fixed in the sky. The earth must then have been drawn out towards the moon, so that its surface was more nearly an ellipsoid with three unequal axes than it is now. The primary effect of the ellipsoidal condition upon the distribution of continent and ocean would be to raise the surface above the ocean near the opposite extremities of the greatest diameter of the equator. But, again, owing to the eccentric position of the centre of gravity, there would be an important secondary effect. The gravitational attraction of an ellipsoid differs from that of a sphere, and it may be represented as the attraction of a sphere together with an additional attraction. If the density was greater in one hemi-ellipsoid than in the other, the additional attraction would produce a greater effect in the parts where the density was in excess, and the result, just as in the case of rotation, would be a furrowing of the surface. It has been proved that the formula for this furrowing also is expressed by a spherical harmonic of the third degree.

We are brought to the theory of spherical harmonics and the spherical harmonic analysis. Spherical harmonics are certain quantities which vary in a regular fashion over the surface of a sphere, becoming positive in some parts and negative in others. I spoke just now of making a model of a nearly spherical surface by removing material from some parts and heaping it up on others. Spherical harmonics specify standard patterns of deformation of spheres. For instance, we might remove material over one hemisphere down to the surface of an equal but not concentric sphere (*cf.* fig. 5) and heap up the material over the other hemisphere. We should produce a sphere equal to the original but in a new position. The formula for the thickness of the material removed or added is a spherical harmonic of the first degree. It specifies the simplest standard pattern of deformation. Again, we might remove material from some parts of our model and heap it up on other parts so as to convert the sphere into an ellipsoid. The formula for the thickness of that which is removed or added is a spherical harmonic of the second degree. Deformation of a sphere into an ellipsoid is the second standard pattern of deformation. The mathematical method of determining the appropriate series of standard patterns is the theory of spherical harmonics. Its importance arises from the result that any pattern whatever can be reached by

first making the deformation according to the first pattern, then going on to make the deformation according to the second pattern, and so on. If we begin with a pattern, for instance the shape of the earth, which is not a standard pattern, we can find out how great a deformation of each standard pattern must be made in order to reproduce the prescribed pattern. The method of doing this is the method of spherical harmonic analysis. Except in very simple cases the application of it involves rather tedious computations. With much kind assistance and encouragement from Professor Turner, I made a rough spherical harmonic analysis of the earth's surface. I divided the surface into 2,592 small areas, rather smaller on the average than Great Britain, gave them the value +1, or one unit of elevation, if they are above the sea, and the value −1, or one unit of depression, if they are below the 1,400-fathom line. To the intermediate areas I gave the value 0. The distribution of the numbers over the surface was analysed for spherical harmonics of the first, second, and third degrees.

Any spherical harmonic of the first degree gives us a division of the surface into two hemispheres—one elevated, the other depressed. The spherical harmonic analysis informs us as to the position of the great circle which separates the two hemispheres, and also as to the ratio of the maximum elevation of this pattern to the maximum elevation of any other pattern. The central region of greatest

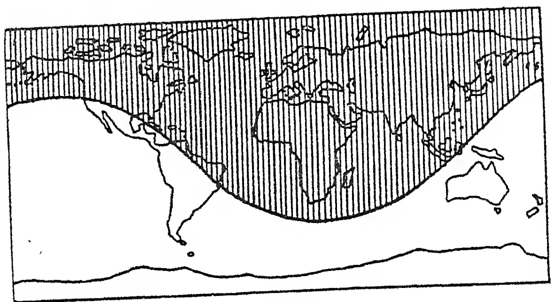


Fig. 6.

elevation of this pattern is found to be in the neighbourhood of the Crimea, and the region of elevation contains the Arctic Ocean and the northern and central parts of the Atlantic, Europe, Africa, Asia, most of North America, and a small part of South America. When the surface is mapped on a rectangle in the same way as before, the chart of the harmonic is that shown in fig. 6.[1] The actual disproportion between the amounts of continental area in the northern and southern hemispheres is associated with the result that the central region of elevation, as given by the analysis, is about 45° north of the equator; and the extension of the Pacific Ocean and adjoining Southern Ocean to much higher southern than northern latitudes is associated with the corresponding position of the central region of greatest depression about 45° south of the equator. In regard to harmonics of the second degree, the spherical harmonic analysis informs us as to the ellipticity of the equator and the obliquity of the principal planes of that ellipsoid which most nearly represents the elevation of the surface above or its depression below the surface of the ocean, or the geoid. The result is an equatorial region of depression, which spreads north and south unequally in different parts and forms a sort of immense Mediterranean, containing two great basins, and separating a northern region of elevation from a southern. The northern region of elevation occupies the northern part of the Atlantic Ocean and runs down to and across the equator in the neighbourhood of Borneo. The southern region of elevation occupies the southern part of the Pacific Ocean, and it runs up to and across the equator in the neighbourhood of Peru. The chart of the harmonic is shown in

[1] In this figure, and in the following figures, regions of elevation are shaded, and regions of depression are left blank.

fig. 7. The equatorial regions of elevation given by the analysis are near the ends of a diameter, as we should expect.

It has not been necessary to enter into a minute description of the harmonics of

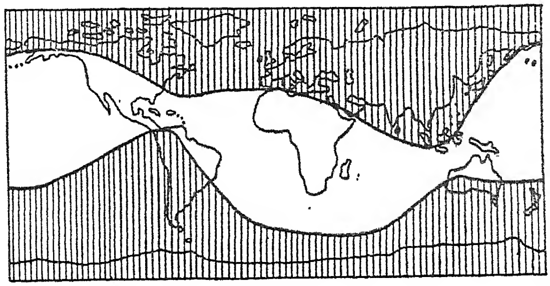


Fig. 7.

the first and second degrees, because they represent very simple things—a shifting of the surface to one side and a distortion of it into an ellipsoid. The harmonics of the third degree are not so familiar. There are essentially four of them, each

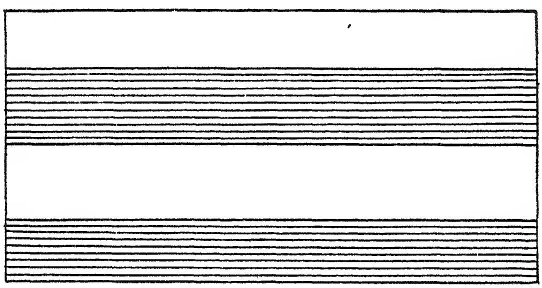


Fig. 8.

specifying a standard pattern of deformation. The first of these, the zonal harmonic, gives us a division of the surface into two polar caps and two zones by means of the equator and the parallels of latitude about 51° north and 51° south.

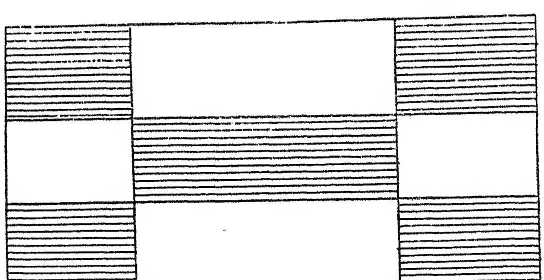


Fig. 9.

Alternate zones are depressed and elevated, as shown in fig. 8. The existence of an Antarctic continent and an Arctic Ocean is specially associated with the presence of this harmonic, and the disproportion of the continental areas in the

northern and southern hemispheres is also connected with it. The second of the harmonics of the third degree, the tesseral harmonic of rank 1, gives us a division of the surface into six half-zones by means of a complete meridian circle and the parallels of latitude about 27° north and 27° south. Alternate half-zones are depressed and elevated as shown in fig. 9. The combined effect represented by the zonal harmonic and the tesseral harmonic of rank 1 is a furrowed surface with an Arctic region of depression extending southwards in the direction of the Atlantic, a zone of elevation which runs across the Atlantic, South America, and Africa, and then turns northwards at either end, a zone of depression with the same kind of contour, and an Antarctic region of elevation

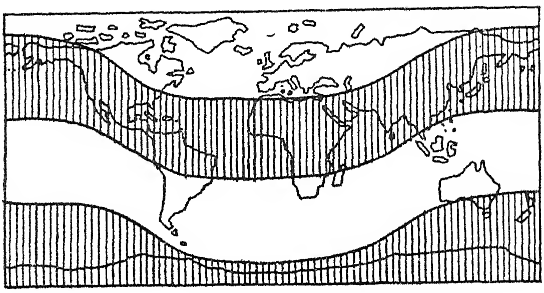


Fig. 10.

which extends northwards in the direction of Australasia. These regions are shown in fig. 10. I have recorded the result of combining these two harmonics because they represent the particular effects that would be produced by the interaction of two causes—the rotation, and the eccentric position of the centre of gravity. The third type of harmonics of the third degree, the tesseral harmonic of rank 2, gives us a division of the surface into octants by means of the equator and two complete meridian circles. Alternate octants are elevated and depressed

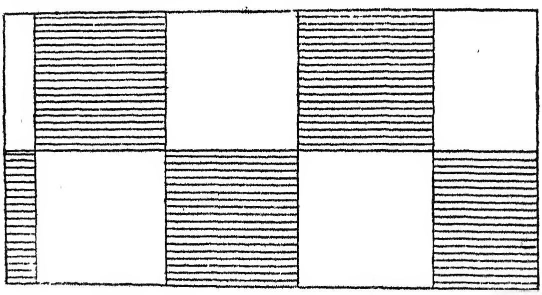


Fig. 11.

as shown in fig. 11. We can name the octants where there is elevation: Asia, Australasia, North America, South America. The harmonic of this type is certainly prominent. It is specially associated with the skew position of South America to the east of North America. The fourth type of harmonics of the third degree, the sectorial harmonic, gives us a division of the surface into six sectors by means of three complete meridian circles. Alternate sectors are depressed and elevated as shown in fig. 12. The southward tapering of Africa is specially associated with the harmonic of this type. The combined effect of all the harmonics of the third degree is shown in fig. 13. It represents the sphere deformed into a sort of irregular pear-shaped surface. The stalk of the pear is in the southern part of Australia and contains Australasia and the Antarctic continent.

This is surrounded on all sides but one (towards South America) by a zone of depression, the waist of the pear. This, again, is surrounded on all sides but one (towards Japan) by a zone of elevation, the protuberant part of the pear; and finally we find the nose of the pear in the central Atlantic between the Madeiras and the Bermudas. I do not, however, wish to emphasise the resemblance of the surface to a pear or any other fruit, but prefer to describe it as an harmonic spheroid of the third degree. Another way of regarding it would be as a surface with ridges and furrows. From a place in the South Atlantic there run three ridges: one north-westwards across America, a second north-eastwards across Africa and Asia, and the third southwards over the Antarctic continent, continu-

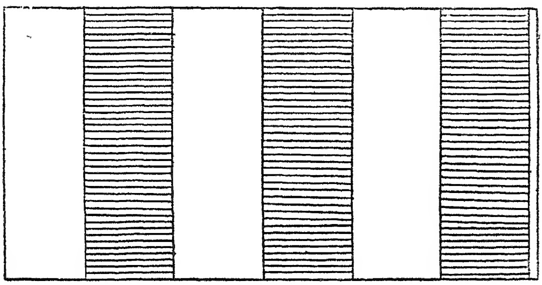


Fig. 12.

ing northwards across Australia nearly to Japan. From the Sea of Okhotsk there run three furrows: one south-westwards across Japan, the Malay Peninsula, and the Indian Ocean; a second south-eastwards across the Pacific; and the third northwards over the Arctic Ocean, continuing southwards by way of the Atlantic. Harmonics of the first and third degrees have in common the character of giving depression at the antipodes of elevation; the harmonics of the second degree give depression at the antipodes of depression and elevation at the antipodes of elevation. The maxima of the harmonics of the first and third degrees are found to

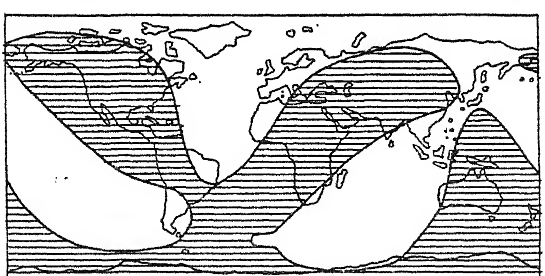


Fig. 13.

be rather greater than the maximum of the harmonic of the second degree. Of three quantities to be added together the two larger ones agree in giving depression at the antipodes of elevation; a result which is in accordance with the fact that most continents have oceanic antipodes.

When we superpose the effects represented by all the various harmonics of the first, second, and third degrees, so as to make, as it were, a composite photograph of all the various elevations and depressions represented by them severally, each in its appropriate amount as determined by the harmonic analysis, we find the curve shown in fig. 14 as the theoretical curve of separation between regions of elevation and depression which are approximately equal in area.

I showed before a smoothed curve (fig. 3) which I proposed to take as representing the facts to be accounted for. The resemblance of the two curves seems to be striking. Incidentally it has been noticed how the prominent features of the distribution of continent and ocean are associated with the presence of various harmonics. As regards the contour of the great ocean basins, we seem to be justified in saying that the earth is approximately an oblate spheroid, but more nearly an ellipsoid with three unequal axes, having its surface furrowed according to the formula for a certain spherical harmonic of the third degree, and displaced relatively to the geoid towards the direction of the Crimea.

As regards the amount of elevation and depression in different parts, the agreement of the theory with the facts is not so good. The computed elevation is too small in Southern Africa, Brazil, and the southern part of South America, too great in the Arctic regions, to the south of Australasia, and in the Mediterranean region. There are many reasons why we could not expect the agreement to be very good. One is the roughness of the method of harmonic analysis that was used. But there is also the fact that many causes must have contributed to the shaping of our actual continents and oceans besides those which have been taken into account in the theory. It appears, however, that the broad general features of the distribution of continent and ocean can be regarded as the consequences of simple causes of a dynamical character: eccentric position of the centre of gravity, arising from a past state of inadequate resistance to compression, an inherited tendency, so to speak, to an ellipsoidal figure, associated with the

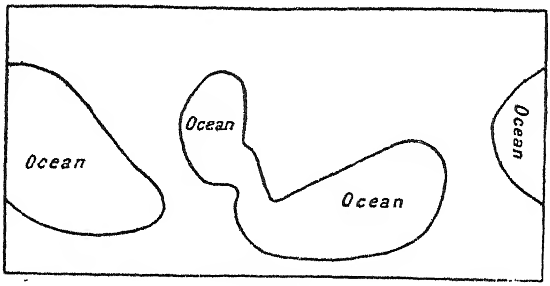


Fig. 14.

attraction of the moon in a bygone age, the rotation, and the interactions of these various causes.

In attempting to estimate the bearing of the theory on geological history we must be guided by two considerations. The first is that the earth is not now gravitationally unstable. From observations of the propagation of earthquake shocks to great distances, we can determine the average resistance to compression, and we find that this resistance is now sufficiently great to keep in check any tendency to gravitational instability. The eccentric position of the centre of gravity must be regarded as a survival from a past state in which the resistance to compression was not nearly so great as it is now. The second guiding consideration is that, according to the theory, the inequalities which are expressed by spherical harmonics of the third degree are secondary effects due to the interaction of the causes which give rise to inequalities expressed by harmonics of the first and second degrees. We should expect, therefore, that the inequalities of the third degree would be much smaller than those of the first and second degrees; but the harmonic analysis shows that the three inequalities are entirely comparable. We must conclude that the harmonics of the first and second degrees which we can now discover by the analysis are survivals from a past state, in which such inequalities were relatively more important than they are now. Both these considerations point in the same direction, and they lead us to infer that certain secular changes may have taken place in the past, and may still be going on. Sixty-nine years ago Charles Darwin wrote: 'The form of the fluid surface of the nucleus of the earth is subject to some change the cause of which is entirely

unknown, and the effect of which is slow, intermittent, but irresistible.' Forty-two years later Sir George Darwin showed that any ellipsoidal inequality in the figure must be gradually destroyed by an irreversible action of the same nature as internal friction or viscosity. The same may be said of a state in which the centre of gravity does not coincide with the centre of figure when the resistance to compression is great enough to keep in check the tendency to gravitational instability. The state would be changed gradually in such a way as to bring the centre of gravity nearer to the centre of figure. A symptom of such changes might be the occurrence of great subsidences in the neighbourhood of the Crimea, where we found the maximum of the first harmonic. Such subsidences are supposed by geologists to have taken place in rather recent times. Symptoms of the diminution of the inequalities expressed by harmonics of the second degree would be found in the gradual disappearance of seas forming part of the great depression which was described above as a sort of immense Mediterranean (*cf.* fig. 7) in the destruction and inundation of a continent in the northern Atlantic and in a gradual increase of depth of the Southern Pacific. The disappearance of seas from a vast region surrounding the present Mediterranean basin, and containing the Sahara and Southern Asia as far east as the Himalayas, is one of the best ascertained facts in geological history; and the belief in the destruction of a north Atlantic continent is confidently entertained. In parts of the Southern Pacific a depression represented by harmonics of the third degree is superposed upon an

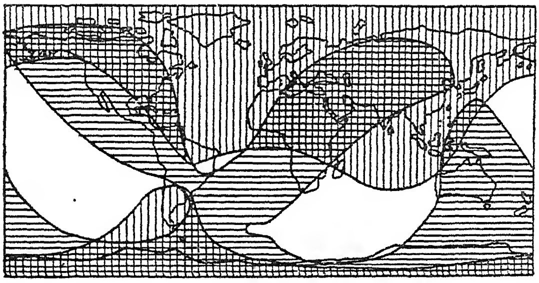


Fig. 15.

elevation represented by harmonics of the second degree, and we should therefore expect to find the depth of the ocean to be increasing gradually in this region. The region in question is that of the coral reefs and coral islands, such as Funafuti, and the result is in accord with Darwin's theory of the formation of coral reefs. So far as the general distribution of the mass within the earth is concerned, the reduction of the inequalities of the first and second degrees would seem to have already proceeded very far; for we are assured by geodesists that harmonics of the first degree, and those of the second degree which do not represent the effect of the rotation, are far from prominent in the figure of the geoid—much less prominent than we found them to be in the distribution of continent and ocean. We infer that the inequalities of the first and second degrees must have been progressively diminished in comparison with those of the third degree. The general result of such changes would be a gradual diminution of the depths and extents of the oceans which correspond with the harmonics of the first and second degrees, and a compensating increase in the depths and extents of the oceans which correspond with the harmonic of the third degree. To see the character of the changes which would thus be brought about, we may examine a figure which shows the composite elevations and depressions that are represented by harmonics of the first and second degrees, and, separately, those which are represented by harmonics of the third degree. In fig. 15 the composite elevations of the first and second degrees are shaded vertically, and the elevations of the third degree are shaded horizontally. The deep parts of the Atlantic that border the coasts everywhere from Brazil to Ashanti are regions in which a depression represented by the third harmonic is

superposed upon an elevation represented by the other two harmonics, and the same is true of the deep parts of the Indian Ocean which border the shores of Africa and Asia from Madagascar to Burmah. The deep parts of the Pacific that border the western coast of America from Alaska to Chile are regions in which an elevation represented by the third harmonic is superposed upon a depression represented by the other harmonics. These observations suggest that in the greater part of the Atlantic and the northern and western parts of the Indian Ocean the direction of sæcular change may have been that of an advance of the ocean to encroach upon the continental region, while in the Pacific Ocean on the American side the direction of sæcular change may have been that of a retreat of the ocean, permitting an extension of the continental region. This difference would lead us to expect different types of coast in the two regions, and such a difference has been observed. Whereas in the Atlantic region, with few exceptions, the coast cuts across the directions of the mountain chains, in the Pacific region on the American side the coast generally corresponds in direction with the neighbouring mountain chains of the continent. The deep parts of the Pacific which are nearest to the Asiatic coast from Kamchatka to Siam are regions where a moderate depression represented by the third harmonic is superposed upon a moderate elevation represented by the other harmonics. These shores of the Pacific are distinguished by the wide margin which separates the deep ocean from the coast of the continent. It might perhaps be desirable to recognise in this region a type of coast differing from the two main types associated with the Atlantic and the American side of the Pacific. The analysis does not represent South Africa or the southern parts of South America sufficiently well to warrant us in expecting these regions to exhibit one type rather than the other; but the way in which Australia is represented, as an elevation of the third degree superposed upon a depression of the first, suggests that the coasts of Australia, and especially the eastern coast where the elevation in question is greater, should be of the same type as the American shores of the Pacific; and it is the fact that the mountain chains of Queensland and New South Wales run parallel to the neighbouring coasts. There seems therefore to be much evidence to support the view that the direction of sæcular change has been that of diminishing the prominence of the inequalities of the first and second degrees in comparison with those of the third degree. The process by which such changes would be brought about would be of the nature of relief of strain, expressing itself in occasional fractures of no very great magnitude; and such fractures would be manifested at the surface as earthquakes. Seismic and volcanic activities constitute the mechanism of the process of change. These activities are spasmodic and irregular, but the effect of them is cumulative. For this reason they tend in the course of ages to transform the shape of the earth from one definite type to another. The diminishing speed of the earth's rotation is another cause of change which appears to produce an alternating rather than a cumulative effect. On the one hand it tends to diminish that tendency, which we noted above, to draw the waters of the ocean towards equatorial regions; on the other hand it must result in an actual reduction of the equatorial protuberance of the earth's figure. This reduction can only be effected by seismic activity expressed by subsidences in equatorial regions. The effect which would in this way be produced in the distribution of continent and ocean would appear to be that there would be long periods in which the ocean would tend to advance towards the Arctic and Antarctic regions, interrupted by shorter periods in which it would tend to retreat towards the neighbourhood of the equator.

The theory which I have tried to explain is a tentative one, and further investigation may prove it to be untenable; but it is to its credit that, besides tracing to dynamical causes the existing distribution of continent and ocean, it offers an explanation of the difference between the Atlantic and Pacific types of coast, it gives indications of a possible account of those alternations of sea and land which first led to the study of geology, and it suggests an origin for Charles Darwin's unknown force, the operation of which is slow and intermittent, but irresistible.

The following Papers were then read:—

1. *Helium and Radio-activity in Common Ores and Minerals.* *By* Hon. R. J. STRUTT, *F.R.S.*

2. *On the Motions of Ether produced by Collision of Atoms or Molecules containing or not containing Electrons.*[1] *By* Lord KELVIN, *G.C.V.O.*, *F.R.S.*

3. *On Secular Stability.* *By* Professor HORACE LAMB, *F.R.S.*

The author showed an experiment intended to illustrate the distinction between 'ordinary' or 'temporary' stability and 'permanent' or 'secular' stability, to which attention has been drawn by Poincaré in his research on figures of equilibrium of rotating liquid. A pendulum, symmetrical about its axis, hangs by a Hooke's joint from the lower end of a vertical spindle, which can be made to rotate by means of a pulley with constant angular velocity ω. When $\omega = 0$, the vertical position is of course stable, and the two normal modes of small oscillation have equal periods. For the present purpose these modes may be analysed into two circular vibrations in opposite directions. When the spindle is made to rotate, the usual method of 'small oscillations,' which ignores the effect of dissipative forces, leads to the conclusion that the vertical position is still 'ordinarily' stable for all speeds, the only effect of the rotation being that the two circular vibrations have now different periods, that being the more rapid whose direction of revolution agrees with that of the shaft. The criterion of 'secular' stability imposes, however, a limit to the value of ω. If A, A, C be the principal moments of inertia of the pendulum at the joint, M the mass, h the depth of the centre of gravity below the joint, the condition of secular stability is

$$\omega^2 < \frac{Mgh}{A - C}.$$

If ω^2 exceed this limit, a new position of relative equilibrium is possible, in which the pendulum would rotate at a constant inclination, θ, to the vertical, given by

$$\cos \theta = \frac{Mgh}{(A - C)\omega^2};$$

this position is 'secularly' stable, and the former now unstable.

The latter conclusion is confirmed and explained if we work out the question by the usual method of small oscillations, introducing, however, frictional forces proportional to the relative velocities at the Hooke's joint. It then appears that, as regards the two circular vibrations, the amplitude of the one whose direction agrees with that of the shaft exponentially *increases* (when ω^2 exceeds its critical value), whilst that of the other diminishes. Hence the pendulum if disturbed ever so little from the vertical position describes an ever-widening conical path in the direction of the rotation of the shaft, tending towards the second position of relative equilibrium above referred to.

FRIDAY, AUGUST 2.

Discussion on the Constitution of the Atom, opened by Professor E. RUTHERFORD, *F.R.S.*

[1] *Electrician*, August 16, 1907; *Phil. Mag.*, September 1907.

The following Papers and Report were read:—

1. *On Variability in the Products resulting from Changes in Radium Emanation.* By Sir WILLIAM RAMSAY, *K.C.B., F.R.S.*

2. *Pseudo-high Vacua.* By F. SODDY *and* T. D. MACKENZIE.

The electrical characteristics of a high vacuum occur in helium, purified by calcium, and subjected to further purification by the passage of the discharge at pressures between $\frac{1}{3}$ and $\frac{2}{3}$ mm. of mercury, while in hydrogen the same holds at about $\frac{1}{25}$ mm. These pressures are far higher than is commonly supposed. Pure helium conducts at pressures higher than $\frac{2}{3}$ mm. of mercury in the same way as common gases. In brief, the behaviour of helium is precisely similar to that of argon or a common gas like nitrogen at about one-tenth the pressure. This explains not only the extraordinary resistance at low pressure, but also the extraordinary conductivity of the gas at atmospheric pressure. The absorption of helium, argon, and neon in spectrum tubes after continuous running occurs mainly in the volatilised film of aluminium deposited from the electrodes. The gas can be mainly recovered by dissolving the film in mercury or heating the tube. In the latter case it is reabsorbed on running with extraordinary rapidity. The portion causing the Campbell-Swinton effect is only a small fraction of the total.

3. *On the Range of Freedom of Electrons in Metals.*[1] By Professor J. LARMOR, *Sec.R.S.*

It was remarked that perhaps the most obscure present problem in abstract physics is the mechanism of the transfer of electricity (the electron) from molecule to molecule. A hopeful plan is to study it in its time-relations; the optical phenomena of metals introduce times, the periodic times of the vibrations, that are small enough for this purpose.

The experiments of Hagen and Rubens show that the behaviour of metals to long infra-red radiation depends on their steady ohmic resistance alone. Thus the time required to establish conduction completely is a small fraction of the period of such waves. If the same free electrons to which conduction is due have velocity of mean square determined by the gas-laws, this restricts their range of freedom almost to the interspace between the molecules. On the other hand, the fact that the square of the *quasi*-index of refraction of light for the nobler metals is not far removed from being a real negative quantity, indicates that the number of such free electrons is of about the same order of magnitude as the number of the molecules. This again recalls the electrochemical principle that the number of *transferable* electrons in an atom represents its valency.

4. *Report of the Committee on Electrical Standards.*—See Reports, p. 73.

MONDAY, AUGUST 5.

The following Papers were read:—

1. *Optical Pyrometry.* By Dr. L. HOLBORN.

If one wishes by means of the radiation from a body to obtain its temperature, it is necessary to recognise that the radiation depends, not only upon the temperature, but also upon the emissive power of the radiating body. We deal first, therefore, with the radiation of a black body which we take as the standard. For each temperature and wave-length it emits the maximum possible amount of radiation, and can be realised by means of a uniformly heated inclosure from

[1] For details see *Phil. Mag.*, August 1907.

which the radiation escapes through a small opening. For this radiation, which may be called 'black-body radiation,' the following laws hold good:—

$$(1) \quad \int_0^\infty E_\lambda d\lambda = aT^4 \quad \text{(Stefan-Boltzmann)}$$

$$(2) \quad \left.\begin{array}{r} \lambda_{max.}T = C_1 \\ \text{and } E_{max.}T^{-5} = C_2 \end{array}\right\} \quad \text{(From Wien's displacement law)}$$

$$(3) \quad E_\lambda = C\frac{\lambda}{e^{\frac{c}{\lambda T}} - 1} \quad \text{(Planck)}$$

Here, T denotes the absolute temperature, E_λ the energy radiated between the wave-lengths λ and $\lambda + d\lambda$, and a, C_1, C_2, C and c are constants.

On all these equations measurements of temperature can be based. The most important from this point of view is the third law (which gives the increase of each portion of the radiation with the temperature), especially in the simplified form

$$(3a) \qquad E_\lambda = C\lambda^{-5}e^{-\frac{c}{\lambda T}} \quad \text{(Wien)}$$

which is valid for small wave-lengths in the visible region. In this case the eye can be employed instead of a bolometer, so that the measurement of temperature can be carried out by means of a photometer. If the luminosities E_1 and E_2 correspond to the radiation E_λ at the absolute temperatures T_1 and T_2, we have—

$$\log \frac{E_2}{E_1} = \frac{c}{\lambda}\left\{\frac{1}{T_1} - \frac{1}{T_2}\right\}$$

If the constant c is known one must select an initial temperature, and can then determine all other temperatures by a comparison of luminosities with that at this standard temperature. For λ one chooses for this purpose a narrow region in the red, in order to have sufficient brightness even at low temperatures.

The accuracy of the constant c depends upon data obtained with the gas thermometer at temperatures corresponding to the visible region. The most recent measurements which are based on the nitrogen thermometer between 800° and 1600° C. give for c the value 14,200, which in the visible region is independent of the wave-length.

The accuracy of c may amount to about 1 per cent., so that the temperature measurement, if the melting-point of gold (1064°) is taken as the starting-point, is accurate to 6° at 1500°, to 16° at 2000°, and to 48° at 3000° C. Every spectrophotometer can therefore be employed as a pyrometer. The comparison of the radiation to be measured with a constant source of light is effected in a known way by the reduction of intensity by means of a polariser or a rotating sector. For pyrometric purposes attempts have been made to simplify the spectrophotometer. We shall give the following examples.

The instrument of Wanner is a photometer with polariser which permits observations to be made in the spectral region of the red hydrogen line. The comparison source of light is a small glow-lamp the brightness of which can be controlled from time to time by comparison with an amyl-acetate lamp. The angles which are read on the divided circle of the polariser after adjustment has been made of the two halves of the field of view to equality of brightness are translated into temperatures with the help of a table.

The pyrometer of Holborn and Kurlbaum employs a variable comparison source of light, and this also is a small glow-lamp the brightness of which can be adjusted by means of an alteration of current-strength, so that the middle of the carbon filament becomes invisible when in front of the glowing surface whose light is being determined. The indication of temperature is furnished, therefore, by the strength of current through the lamp, which before use is standardised by reference to a black body of measurable temperature.

Instead of an arrangement for producing a spectrum, the second instrument employs coloured glasses. The less homogeneous light which is furnished is of no disadvantage if we base the standardisation of the readings of the instrument on the black body. But if in the measurements made with the pyrometer one wishes to employ Wien's law, for example, by which one somewhat extrapolates the temperature scale, then the effective wave-length must first of all be determined from the law of radiation by means of a special investigation. Determinations up to about 1600° indicate that the effective wave-length transmitted by the most common copper-oxide glass is constant, and is equal to ·650μ.

From optical measurements based on the melting-point of gold (1064°) are obtained the following melting-points: Palladium, 1580°; platinum, 1790°; rhodium, 2000°.

The highest temperature which up till now has been determined with the gas-thermometer is that of palladium. The value obtained was 1575°.

If we employ the optical pyrometer, which has been standardised by means of a black body, on a body of smaller radiating power, we do not obtain the true temperature, but a less value, which in distinction from the true temperature we call the *black temperature*. It is that temperature at which a black body will be if it radiates in the region of the spectrum which is investigated with the same brightness as the body of less radiating power. In many cases one can inclose the radiating body, if its emissive power is not known, in a cavity or in a reflecting envelope, and in this way make its radiation that of a black body. In other cases the emissive power must be specially determined.

For the noble metals, such as silver, gold, and platinum, measurements have furnished a simple result. The emissive power (relative to that of a black body at the same temperature) for these metals for a given wave-length in the visible region is independent of the temperature within the accuracy of the measurements of temperature. Thus platinum emits red light of about one-third, gold of one-eighth, and silver of one-fourteenth of the brightness of a black body at the same temperature. The law is valid down to low temperatures where we can determine the emissive power from the absorption of good metallic mirrors.

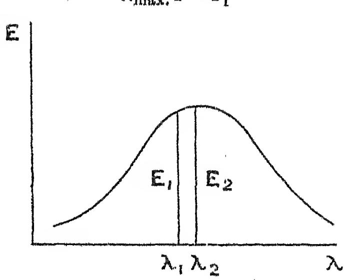
2. *Optical Pyrometry.* *By* Professor C. FÉRY.

Of all methods of temperature measurement those based upon the laws of radiation are certainly the most exact, and they lend themselves readily to the construction of instruments which do not vary in their indications, as they are not subjected to the destructive influences of hot furnace-gases or of the substances under experiment.

In the first place I should like to say a few words concerning the formulæ upon which temperature measurements may be based.

I. *The 'Displacement Law' of Wien*

$$\lambda_{max.}T = C_1$$



does not lend itself to exact measurement. This law may be expressed by saying that the product of the absolute temperature of a 'black body' and the intensity of radiation of the dominant wave-length is constant.

It is well known that the determination of the exact position of the maximum ordinate of a curve is very difficult in practice. It is obvious that the error in the dominant wave-length, resulting from a very small error in estimating the amount of energy, would be extremely large, owing to the flatness of the top of the curve, and the error in the temperature would be correspondingly great.

II. *Law of Monochromatic Radiation.*

Although still almost empirical, exponential laws of the form

$$E_\lambda = C\epsilon^{-\frac{a}{T}},$$

which give the value of the intensity of radiation for a given wave-length as a function of the absolute temperature T, agree very well with experimental results. They are very suitable as a basis for the construction of pyrometers on the principle of monochromatic photometry or spectrophotometry, which are well known, and of which the optical pyrometer of Chatêlier and Wanner and the absorption pyrometer of Féry and those of Holborn and Kurlbaum are examples.

In such apparatus it would appear advisable to obtain photometric balance by diminishing the brilliancy of the body under test rather than by increasing the brilliancy of the comparison lamp, which may detract from its electrical efficiency and subject it to unduly severe treatment. This diminution may be effected by a diaphragm (le Chatêlier), by absorption (Féry), or by polarisation (Wanner).

On the other hand the regulation of the brightness of the comparison lamp (Holborn-Kurlbaum or Morse) has the advantage of great simplicity of construction and regulation. We are restricted, however, under these circumstances to the measurement of temperatures below 1300° or 1400°, the maximum allowable temperature of the lamp filament.

III. A law which is much more rigorously established from the theoretical standpoint is that of Stefan-Boltzmann, or the law of the fourth power. It is too well known for there to be any necessity to insist either upon its theoretical basis or upon its numerous experimental verifications.

There are, however, a few considerations which may advantageously be kept in view in applying this law to pyrometric measurements. Some concentrating device, either lens or mirror, is generally necessary, and I have frequently insisted upon the difficulty of finding a transparent substance having no selective absorption, *i.e.*, an *impartial* absorption of radiations of all wave-lengths. Such a substance would enable an instrument to be constructed which could be calibrated by a single experimental check.

The same difficulties present themselves when employing a metal reflector to concentrate the heat upon a thermo-pile.

A similar remark must be made concerning the absorbing power of the black substance (lamp-black or platinum-black) with which the heated junction is covered. It would be an advantage to make this junction concave in order more perfectly to realise the theoretical conditions.

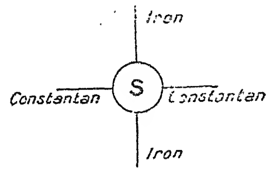
Lastly, if we consider a little more in detail the mode of operation of a thermo-junction heated by radiation, we see that temperature equilibrium results when the gain of heat by absorption is exactly compensated by the loss (*a*) by conduction through the wires of the thermo-element, (*b*) by convection, and (*c*) by the radiation from the heated junction.

If we may assume that the loss of heat due to the first two causes is proportional to the excess of the temperature of the junction over that of its enclosure, this is not the case with that due to the third cause, which is proportional to the difference of the fourth powers of the temperatures in accordance with the law of radiation.

It therefore results that, if we could obtain in practice a thermometric body suspended in an *exhausted* enclosure by a *perfectly heat-insulating thread*, the rise of temperature would follow a more complex law than that of Stefan as a function of the temperature of the radiating source.

But in industrial apparatus, and even in those for accurate measurement, it is apparently always assumed that the cooling of the thermometric detector, bolometer wires, or thermo-pile, &c., follows a linear law. Nothing more is necessary to show, at least theoretically, that if the Stefan law is verified in radio-pyrometry, it must only be approximate.

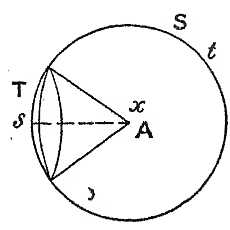
It may be of interest to obtain some idea of the magnitude of each of the cooling effects. It is practically certain that the principal of these is generally the thermal conductivity of the wires of the thermo-junction. I have, however,



been able to produce thermo-junctions in which an increase of the area S exposed to the radiation produces no perceptible increase of voltage, showing that the most important loss has been eliminated.

It may be asked what the temperature of the thermo-element would be if it were *in vacuo,* and thereby removed from the cooling influence of air currents. In an industrial instrument the rise of temperature never exceeds 100° C.

But in these instruments, the diameter of the mirror being equal to its focal length, it is easily seen that the surface of this mirror is $\frac{1}{16}$th of the total surface



of the sphere of which it forms part, and in consequence the ratio of the surface s of the mirror to that of the cooling surface S is $\frac{1}{16}$.

If the junction A is *in vacuo,* we have, as the condition of equilibrium, $T^4 - x^4 = 15(x^4 - t^4)$, assuming that the only loss is that by radiation. Here T is the *apparent* temperature of the mirror s, which *is equal to that of the furnace,* t that of the telescope body (temperature of the enclosure), and x the temperature attained by the junction. From this formula we find that for T = 1500° abs. and t = 300° abs. x = 750° abs. approximately.

This calculation shows how great must be the loss by convection when, as in practice, where the loss by conduction has been rendered very small, the temperature of the junction is only 100° C.

This investigation also explains why the bolometer is so sensitive to the smallest air-currents. The temperature of the grid, by the fact of the passage of the current, is always much higher than that of a thermo-pile under the same conditions.

On the other hand it shows that, even when the conduction loss is rendered negligible, the loss by convection (which may be taken as linear for small differences of temperature between the junction and the surrounding air) is so great that it masks the loss by radiation. The latter cannot therefore seriously affect the proportionality of the indications of the instrument.

Nevertheless this last form of radio-pyrometer has found much favour in factory practice, and I would conclude by mentioning that an apparatus of this

kind has been devised in which there is nothing electrical, the thermometric receiver, instead of a thermo-element, being a bimetallic spiral, which deflects a pointer over a scale attached to the instrument.

Department of Mathematics.

The following Papers were read:—

1. *An Account of Modern Work on the Calculus of Variations.* *By* Professor A. R. Forsyth, *F.R.S.*

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2. *Some New Results in the Theory of Functions of a Real Variable.* *By* Dr. W. H. Young, *F.R.S.*

I. *The Distinction of Right and Left at a Point of Discontinuity.*

1. *Definition of the Associated Functions.*—Let P be any internal point of a segment in which f is defined. Take an interval with P as right-hand end-point; then $f(x)$ has, for points internal to this interval, an upper limit; as the interval decreases this upper limit cannot increase, and therefore has a limit $\phi_L(P)$. This function is called the upper left-hand limiting function of f.

Similarly we define the upper right-hand limiting function ϕ_R, and the lower left-hand and right-hand limiting functions ψ_L and ψ_R.

Further, at each point we select that one of the two upper functions which is not less than the other; the function so defined is called the (modified) upper limiting function ϕ.

The word modified is introduced to mark the distinction between this function and what I have elsewhere called the upper limiting function, and which I now call Baire's upper limiting function, and denote by ϕ_B. This is that one of f and ϕ which is not less than the other.

Similarly, changing less to greater and upper to lower, we have the lower limiting function ψ.

2. If f is bounded (borné), so are the limiting functions. If not they will have proper infinite values, even when f is always finite; e.g., $f=0$ at irrational points, $f=q$ at any rational point $\frac{p}{q}$.

It is easily proved that the points where one of the upper limiting functions $=+\infty$ form a closed set, and where it $=-\infty$ an inner limiting set.

3. *Theorem* 1.[1]—Any limit approached by any upper limiting function (modified or not) as x approaches a point P as limit on the left $\leqslant \phi_R(P)$, and as x approaches P as limit on the right $\leqslant \phi_L(P)$.

Cor. 1.—ϕ_L is upper semi-continuous on the left and ϕ_R on the right, while ϕ, like ϕ_B, is an upper semi-continuous function, and, as such, at most pointwise discontinuous.

Cor. 2.—At any point where $\phi_L=\phi_R=\phi$, both ϕ_L and ϕ_R are upper semi-continuous (on both sides). (N.B.—The converse is not true.)

4. *Theorem* 2.—At every point of continuity of ϕ, $\phi_L=\phi_R=\phi$, and both ϕ_L and ϕ_R are continuous.

Cor.—All the associated upper limiting functions are at most pointwise discontinuous.

(N.B.—Either of the unsymmetrical upper functions may have other points of continuity. Example, $f=0$, except at a sequence on the right of its limiting point, where $f=1$.)

Theorem 3.—The points of continuity of ϕ_B are among those of ϕ, so that at

[1] In the statements of theorems we usually confine ourselves to the ϕ's. The corresponding statements for the ψ's are obvious.

each $\phi_B = \phi = \phi_L = \phi_R \geqslant f$; at any point of continuity of ϕ, which is not a point of continuity of ϕ_B; $\phi_B = f > \phi$.

(N.B.—ϕ may have points of continuity other than those of ϕ_B; e.g., $f=0$, except at one or more isolated points, where $f=1$.)

Theorem 4.—The only points where both ϕ_L and ϕ_R are continuous are the points of continuity of ϕ.

5. Similar theorems hold for the lower associated functions. Hence, considering the common points of continuity of the two pointwise discontinuous functions ϕ and ψ, there is no distinction of right and left for f, except possibly at points of an ordinary outer limiting set of the first category.

This is not the utmost that can be said; the complete theorem is:—

Theorem 5.—The points, if any, at which $\phi_R \neq \phi_L$ are countable.

6. Thus we have proved that the points, if any, where there is a distinction of right and left for f are countable.

Example of a function having distinction of right and left at a countable set of points dense everywhere. Make terminating binary points on x-axis correspond to middle points of black intervals of Cantor's typical ternary set on the y-axis, and add 1 to the limiting values at all the remaining points.

7. The reasoning proving Theorem 5 serves to prove the following:—

Theorem 6.—The points, if any, where

$$f > \phi_L, \quad \text{or} \quad f > \phi_R, \quad \text{or} \quad f > \phi$$

are countable.

II. *Non-uniform Convergence and Divergence.*

1. *Definition of the right and left peak and chasm functions.*—Let $f_1, f_2, \ldots$ be a series of functions having a definite limiting function f. Let P be any point; take an interval on the right of P, say (PQ), and let M_n be the upper limit of f_n in (P, Q). Represent these numbers M_n on the y-axis, and let M_Q be the highest point of their first derived set. Now let the interval (P, Q) diminish indefinitely; M never increases, and has therefore a limit π_R (P). This is the right-hand peak function.

Similarly define the left-hand peak function, and, making suitable changes, the right and left chasm functions χ_R and χ_L.

The omission of the subscripts, or of the words right and left, means that we take that one which is in the case of π not less, and in the case of χ not greater, than the other.

2. *Theorems* 1–6 are the same as in Part 1, only using now the peak and chasm functions. (N.B.—Hence we get precisely the same relations of right and left as in the case of the associated functions.)

3. Assuming now that the functions f_n are in the extended sense continuous, the condition for uniform convergence is $\pi = \chi$; it will then follow that $\pi = \chi = f$. This includes what I call uniform divergence when $\pi = \chi = f = \infty$. It may easily be shown that the points of uniform divergence form an inner limiting set. The reasoning used by Osgood, and subsequently by myself, in discussing non-uniform convergence shows that the points of non-uniform convergence and non-uniform divergence together form a set of the first category. Hence it follows that if a series of continuous functions diverges at a set of points dense everywhere in an interval, it diverges uniformly at points which form a set of the second category.

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3. *On a Remarkable Periodic Solution of the Restricted Problem of Three Bodies. By* Dr. W. de Sitter.

In the third volume of his 'Méthodes Nouvelles' Poincaré has devoted a short chapter to what he calls periodic solutions 'de seconde espèce.' The principle of these solutions is the following. Let two bodies with infinitely small masses

move in Keplerian ellipses E_1 and E_2 round their primary. At a certain moment their mutual distances become infinitely small, a great perturbation ensues, and after that the two bodies move again in Keplerian ellipses E_1' and E_2', different from the former. This may be repeated, and Poincaré shows that it is possible that after a finite number of meetings the original orbits E_1 and E_2 are reproduced. The solution is then periodic, and Poincaré further shows that such a solution can remain periodic if the masses are made finite. The shortest distance then, of course, is no longer infinitely small, but only a 'near approach.'

Now an example of an orbit of this kind is offered in the work of Sir George Darwin. It is the orbit $x_0 = 1{\cdot}08$ figured on page 169 ('Acta Mathematica,' vol. xxi.). Darwin's orbit starts with the two bodies in symmetrical conjunction in the middle of the large perturbation. At the end of the part of the orbit construed by Darwin the orbit of the smaller body P has become practically a Keplerian ellipse, with longitude of perihelion ω. (The other body, J, of course continues to move in its circular orbit, the mass of P being zero.) Let the time taken by this first part of the orbit be t_1. The angle between P and J at the end of the time t_1 is then $\pi - nt_1 + \omega$, n being the mean motion of J. Now put

$$(1) \qquad nt_2 = \pi - nt_1 + \omega + \tau$$

where τ is a small angle, the meaning of which will be explained presently. If it so happens that P in the time t_2 has completed a whole number of half-circuits in its elliptic orbit, the perihelion of this ellipse having in the same time advanced through the angle τ, then at the time $\frac{1}{2}T = t_1 + t_2$ the bodies J and P will again be in symmetrical conjunction or opposition, and the orbit will therefore be periodic with the period T.

The condition that this is so is

$$(2) \qquad n't_2 = k\pi$$

where k is any integer and n' the motion of the mean anomaly of P in its ellipse.

Now by Darwin's work the time t_1 and the elements of this ellipse are given as functions of, say, x_0. Then (2) gives t_2 as a function of n', and therefore of x_0. Further, an easy computation will give the perturbation of the perihelion during the time t_2, *i.e.*, the angle τ, as a function of t_2 and of the elements of the ellipse, and therefore of x_0. Thus in (1) all quantities are functions of x_0, and it is possible to choose x_0 so that it shall be satisfied. The periodic solution of the second species is thus perfectly determinate.

From Darwin's figures I find, very roughly,

$$nt_1 = 114^\circ \qquad \omega = 62^\circ$$

and for the elements of the ellipse I find

$$a' = 0{\cdot}37 \qquad e' = 0{\cdot}69 \qquad n'/n = 4{\cdot}24$$

In this very rough approximation we can take $\tau = 0$; we then find from (1) $nt_2 = 128^\circ$; and if we take $k = 3$ we have from (2) $n'/n = 4{\cdot}22$.

It is thus evident that Darwin's orbit $x_0 = 1{\cdot}08$ if not itself periodic is at least very near to the periodic solution of the second species for $C = 39{\cdot}0$. An exhaustive investigation would, of course, involve a considerable amount of computation, which I have not yet found occasion to undertake.

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4. *On Essentially Positive Double Integrals and the Part which they play in the Theory of Integral Equations.* *By* H. Bateman.

§ 1. By an integral equation of the first kind we shall understand an equation of the form

$$f(s) = \int_a^b g(s, t)\phi(t)dt \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which $f(s)$ and $g(s, t)$ are given for values of s lying between c and d, and $\phi(t)$

is the unknown function. An important question is whether there is more than one continuous function $\phi(t)$ for which the equation is satisfied, supposing it to be soluble ; and this leads us to the consideration of the homogeneous equation

$$0=\int_a^b g(s, t)\phi(t)dt \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If no continuous solution (other than $\phi(t)\equiv 0$) of this equation exists, the *characteristic function* $g(s, t)$ is said to be *perfect* for the ranges (c, d) and (a, b).

§ 2. The function $g(s, t)$ in equation (1) is in general not a symmetrical function of its arguments, but if we multiply both sides of the equation by $g(s, x)$ and integrate with regard to s between c and d we obtain an integral equation of the first kind

$$f_1(x)=\int_a^b \kappa(x, t)\phi(t) \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

with

$$f_1(x)=\int_c^d f(s)g(s, x)ds, \quad \kappa(x, t)=\int_c^d g(s, x)g(s, t)ds \quad . \quad . \quad (4)$$

in which the characteristic function $\kappa(x, t)$ is a *symmetrical* function, so that the problem is reduced to one of a simpler character.

§ 3. Starting from equation (3), Professor Hilbert has indicated a very general class of symmetrical function $\kappa(s, t)$ for which the solution of (3) is certainly unique. The characteristic property is that if $\omega(x)$ is any function which is continuous in the interval (a, b), the double integral

$$\int_a^b\int_a^b \kappa(s, x)\omega(s)\omega(x)ds dx \quad . \quad . \quad . \quad . \quad . \quad (5)$$

is essentially positive. A function $\kappa(s, x)$ which satisfies this condition is said to be *definite*. The function $\kappa(x, t)$ given by equation (4) is easily seen to be definite if $g(s, t)$ is perfect for the ranges (c, d) and (a, b).

When one definite function is known it is easy to construct any number of others; for instance, if $\kappa(x, t)$ is definite, and

$$h(x, t)=\kappa(x, t)f(x)f(t) \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$l(x, t)=\int_a^b\int_a^b \kappa(s, y)f(s, x)f(y, t)ds dy \quad . \quad . \quad (7)$$

the function $h(x, t)$ is definite, and $l(x, t)$ is definite if $f(s, x)$ is perfect.

A criterion for determining whether a function $\kappa(x, t)$ is definite or not is furnished by the following theorem due to Hilbert:—

'If $\kappa(x, t)$ is *perfect*, the necessary and sufficient condition that it should be *definite* is that the *singular values* of λ for which the *homogeneous integral equation of the second kind*

$$\psi(s)-\lambda\int_a^b \kappa(s, t)\psi(t)dt=0 \quad . \quad . \quad . \quad . \quad . \quad (8)$$

can be satisfied should be all real and *positive.*'

An elementary proof of this theorem may be based upon the fact that if $K(s, t)$ is the *solving function* of the *integral equation of the second kind*

$$f(s)=\chi(s)-\lambda\int_a^b \kappa(s, t)\chi(t)dt \quad . \quad . \quad . \quad . \quad (9)$$

i.e., a function such that the unknown function $\chi(s)$ is given by the formula

$$\chi(s) = f(s) + \lambda\int_a^b \mathrm{K}(s, t)f(t)dt\ . \qquad . \qquad . \qquad . \qquad (10)$$

the double integral

$$\Omega(\lambda) = \int_a^b\int_a^b \mathrm{K}(s, t)f(s)f(t)dsdt\ . \qquad . \qquad . \qquad . \qquad (11)$$

increases with λ, becoming infinite and changing sign only as λ passes through a singular value for equation (8). When $\lambda = -\infty$, it can be shown that $\Omega(\lambda) = 0$, and when $\lambda = 0$, $\mathrm{K}(s, t)$ reduces to $\kappa(s, t)$. Hence if there are no negative singular values of λ, $\Omega(\lambda)$ is positive for $\lambda = 0$, *i.e.*,

$$\int_a^b\int_a^b \kappa(s, t)f(s)f(t)dsdt$$

is positive; also $f(s)$ is an arbitrary continuous function, and so $\kappa(s, t)$ is definite.

§ 4. The double integral (5) being considered as analogous to a quadratic form, that arising from a definite function corresponds with a quadratic form which is essentially positive. There is, however, a more general expression, viz.,

$$\int_a^b [\omega(s)]^2ds - \mu\int_a^b\int_a^b \kappa(s, t)\omega(s)\omega(t)dsdt \qquad . \qquad . \qquad (12)$$

which also corresponds with this, and we can show that if the function $\kappa(s, t)$ is such that this expression is positive for every continuous function $\omega(s)$, the singular values of λ for equation (8) cannot lie between 0 and μ.

When $\kappa(s, t)$ is not a symmetrical function of s and t the singular values of λ are not necessarily real, as is the case when $\kappa(s, t)$ is symmetrical. Definite information with regard to their nature can be obtained, however, in the following cases, the first of which is mentioned by A. Myller, and is an extension of a theorem in quadratic forms due to Weierstrass :—

(1) If $\kappa(s, t) = -\kappa(t, s)$, the singular values of λ are purely imaginary quantities.
(2) If

$$\kappa(s, t) = \int_a^b f(s, x)g(x, t)dx,$$

where $f(s, x)$ and $g(x, t)$ are real symmetrical functions of their arguments and one of them is definite, the singular values of λ are all real; if both functions are definite the singular values of λ are all positive.

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5. *Operational Invariants.* *By* Major P. A. MacMahon, *F.R.S.*

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6. *A Method of obtaining the Principal Properties of the Exponential Function.* *By* Professor A. E. H. Love, *F.R.S.*

It is desirable to arrange the theory of the exponential function in a form which shall be at once simple, rigorous, and systematic. In order to attach the theory to familiar things, we may begin by attempting to differentiate $\log_{10} x$; for computation with logarithms, the appearance of the logarithmic curve, and the method of differentiation, as applied to simple rational functions, ought to be familiar to students before they proceed to the exponential function. Since

$$h^{-1}\{\log_{10}(x+h) - \log_{10} x\} = x^{-1}\log_{10}(1 + h/x)^{x/h},$$

the process of differentiation naturally introduces the limit

$$\lim_{n=\infty}(1+1/n)^n,$$

and a simple calculation by means of an ordinary table of logarithms suggests that the limit exists and does not differ much from 2·718. The next step is the proof of the existence of this limit. By help of the binomial theorem for positive integral exponents it is easy to prove that, if n is a positive integer, (i.) $(1+1/n)^n$ increases as n increases, (ii.) $(1+1/n)^n$ lies between 2 and 3, and therefore $(1+1/n)^n$ has a limit when n increases indefinitely through positive integral values. Since any positive value of n which is not an integer lies between two consecutive integers, it is easy to deduce that $(1+1/n)^n$ has a limit when n increases indefinitely by continuous variation. The statement that the variation is continuous, or, in other words, that the index n runs through all values, irrational as well as rational, implies that powers with irrational exponents have been defined. In the elementary theory of indices they are not defined. It would seem to be appropriate to state at this stage that such powers are defined by the following property: If A is any real positive number, and α is any real number, rational or irrational, which lies between two rational numbers a and b, then A^α lies between A^a and A^b. The somewhat abstract discussion necessary to prove that this property defines A^α uniquely when α is irrational may be postponed to a later stage.

The conclusion which has been reached is that there is a definite number, between 2 and 3, which is the limit $\lim_{n=\infty}(1+1/n)^n$. We call this number e and we set before ourselves the problem of computing e. By the process already employed we find

$$\frac{d}{dx}\log_a x=\frac{1}{x}\log_a e,\ \frac{d}{dx}\log_e x=\frac{1}{x},\ \text{and thence}\ \frac{de^x}{dx}=e^x.$$

Hence e^x has a differential coefficient which is continuous. We now apply the theorem of mean value to the expression $\phi(x)$, where

$$\phi(x)=e-e^x-(1-x)e^x-\frac{(1-x)^2}{2!}e^x-\ .\ .\ .\ -\frac{(1-x)^{n-1}}{(n-1)!}e^x-\frac{(1-x)^n}{n!}\mathrm{R}$$

and

$$\mathrm{R}=n!\left[e-1-1-\frac{1}{2!}-\frac{1}{3!}-\ .\ .\ .\ -\frac{1}{(n-1)!}\right].$$

This expression $\phi(x)$ vanishes when $x=1$ and also when $x=0$. We find

$$\phi'(x)=\frac{(1-x)^{n-1}}{(n-1)!}(-e^x+\mathrm{R}).$$

Now $\phi'(x)$ must vanish for some value of x between 0 and 1. Let a be this value; then $\mathrm{R}=e^a$, and we have

$$e=1+1+\frac{1}{2!}+\frac{1}{3!}+\ .\ .\ .\ +\frac{1}{(n-1)!}+\frac{e^a}{n!}\ \text{where}\ 1>a>0.$$

Since e lies between 2 and 3, the term $\dfrac{e^a}{n!}$ is less than $\dfrac{3}{n!}$, and therefore we may compute e with arbitrarily close approximation by the formula

$$1+1+\frac{1}{2!}+\frac{1}{3!}+\ .\ .\ .\ +\frac{1}{r!}.$$

In like manner by writing

$$\phi(x)=e^b-e^x-(b-x)e^x-\frac{(b-x)^2}{2!}e^x-\ .\ .\ .\ -\frac{(b-x)^{n-1}}{(n-1)!}e^x-\frac{(b-x)^n}{n!}\mathrm{R},$$

and

$$\mathrm{R}=\frac{n!}{b^n}\left[e^b-1-b-\frac{b}{2!}-\ .\ .\ .\ -\frac{b^{n-1}}{(n-1)!}\right],$$

we find that $\mathrm{R}=e^a$ for some value of a between 0 and b, and therefore

$$e^b=1+b+\frac{b^2}{2!}+\ .\ .\ .\ +\frac{b^{n-1}}{(n-1)!}+\frac{b^n}{n!}e^a,\ (b>a>0),$$

and it follows that we can compute e^x with arbitrarily close approximation by the formula $1 + x + \frac{x^2}{2!} + \ldots + \frac{x^r}{r!}$. This result is the exponential theorem.

In this method e is introduced as a limit which presents itself naturally, e^x is defined as the xth power of e in accordance with the theory of indices; the differentiations of e^x and of $\log x$ are effected very simply. The proof of the existence of the limit by which e is defined is not intricate. The exponential theorem is presented as a formula for the approximate computation of e^x, and the proof of it is effected by the same process as is used to prove Taylor's theorem (with a remainder after n terms) in the case of functions of a more general character. The theory of infinite series is avoided entirely.

Department of General Physics.

The following Papers and Report were read:—

1. *The Transmission of the Active Deposit from Radium Emanation to the Anode. By* Sidney Russ, *B.Sc.*

A comparison has been made between the amount of active deposit obtained on a wire charged positively and that obtained on the same wire charged negatively at pressures ranging from 0·001 cm. to 10 cms. Diffusion experiments, *i.e.*, experiments made with the wire and containing vessel maintained at the same potential, have also been made over this range of pressure.

Whereas the amount of active deposit obtained on the negative electrode diminishes as the pressure is diminished, as has already been found by Makower, it is found that the amount obtained on a positive electrode increases as the pressure is diminished.

A comparison has next been made of the quantity of active deposit obtained on positive and negative electrodes in different gases at pressures between 0·1 mm. and 1 mm. Up to the time of writing experiments have been completed in air and hydrogen, and the work is being continued for sulphur dioxide.

It is found that whereas in air the amount of active deposit obtained on a negative wire is appreciably greater than on a positive wire over this range of pressure, in the case of hydrogen just as much active deposit is obtained on a positive wire as on the same wire charged negatively.

Thus the quantity of active deposit which is directed by an electric field at these low pressures depends on the nature of the molecules with which the radium emanation is mixed.

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2. *The Absorption of Gases by Charcoal. By* Miss I. Homfray.

The experiments of which an account is here submitted were devised, at the suggestion of Sir W. Ramsay, to throw some light on the question of the absorption of gases in charcoal. The gas which appeared most suitable for the purpose, on account of its molecular simplicity and chemical inertness, was argon. The apparatus used was similar to a constant-volume gas thermometer, the bulb containing 3 grams of charcoal. This was connected with a gas burette, a gas reservoir, and a Sprengel pump, all connections being of glass and sealed.

Various constant temperature baths were used, ranging from boiling water to liquid-air temperatures, and successive quantities of argon were admitted from the burette, the pressures being read at each temperature. Isothermal curves were then plotted, taking pressures as ordinates and concentrations, corrected for dead space and reduced to standard conditions, as abscissæ. From these curves points of equal concentration were read off and a fresh series of curves were obtained, having pressures as ordinates and absolute temperatures as abscissæ. Such curves have been termed by Ostwald 'isosteres.' Each curve corresponds thus to a

vapour-pressure curve in the univariant system of a vapour in contact with its own liquid, and is analogous to it in form.

Ramsay and Young's law for the ratios of absolute temperatures of two vapours at the same pressure was then applied to these results in the form

$$\frac{T_0}{T_1} - \frac{T_0'}{T_1'} = K\,(T_0 - T_0)$$

where T_1 T_1' are the absolute temperatures, read from one of the isostere curves, corresponding to two pressures, and T_0 T_0' the absolute temperatures of any other vapour taken as standard, at the same two pressures. Water, oxygen, and argon were successively taken as standards, and the equation was found to hold for all concentrations. A series of straight lines, one for each concentration, was thus obtained.

It has been shown by Professor Porter that Ramsay and Young's law may be directly derived from Bertrand's vapour-pressure formula $P = G\left(\frac{T-a}{T}\right)^n$ provided that the constant n is the same for all vapours. For a large range of vapours it is found that if $n = 50$ very good correspondence is obtained, and this was found also to be the case with the results of the present experiments.

Values of the other constants a and g were calculated for each concentration as well as for argon vapour itself.

An attempt has been made to correlate these constants with the numbers representing the actual concentrations, and, in order to introduce the argon-vapour constants at a finite concentration, these were calculated in terms of weight of argon in 100 gms. of the mixture—a method frequently used in the case of solutions. The concentrations experimentally reached varied from 0·317 to 7·089 per cent., the vapour in the absence of charcoal being represented by 100 per cent.

For convenience, the logarithms of the concentrations were plotted against values of a and G respectively, and a smooth curve was obtained terminating at 100 per cent. in the constants for argon.

Equations were then obtained which express with considerable accuracy these curves, and when introduced into Bertrand's equation the corresponding temperatures or pressures calculated for any concentration are in very fair agreement with those experimentally found, except for exceedingly small concentrations.

These equations are

$$a = 13{\cdot}12 + \frac{250}{24}\left\{\log\frac{100}{C}\right\}$$

$$\log g = {\cdot}1085 - {\cdot}012\left\{\log\frac{100}{C+1}\right\}$$

where $g = (G)^{\frac{1}{50}}$

The values 13·12 and 0·1085 are the values respectively of a and $\log g$ for argon vapour. The equations given in this paper are in much better agreement with observation than the usually applied logarithmic or exponential equations for the isothermals.

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3. *Report of the Seismological Committee.*—See Reports, p. 83.

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4. *The Density of the Ether. By* Sir OLIVER LODGE, *F.R.S.*

1. The theory that an electric charge must possess the equivalent of inertia was clearly established by J. J. Thomson in the 'Phil. Mag.' for April 1881.

2. The discovery of masses smaller than atoms was made experimentally by J. J. Thomson, and communicated to Section A at Dover in 1889.

3. The thesis that the corpuscles so discovered consisted wholly of electric charges was sustained by many people, and was clinched by the experiments of Kaufmann in 1902.

4. The concentration of the ionic charge, required to give the observed corpuscular inertia, can be easily calculated; and consequently the size of the electric nucleus, or electron, is known.

5. The old perception that a magnetic field is kinetic has been developed by Kelvin, Heaviside, FitzGerald, Hicks, and Larmor, most of whom have treated it as a flow along magnetic lines; though it may also, perhaps equally well, be regarded as a flow perpendicular to them and along the Poynting vector. The former doctrine is sustained by Larmor, as in accordance with the principle of Least Action, and with the absolutely stationary character of the ether as a whole; the latter view appears to be more consistent with the theories of J. J. Thomson.

6. A charge in motion is well known to be surrounded by a magnetic field; and the energy of the motion can be expressed in terms of the energy of this concomitant field,—which again must be accounted as the kinetic energy of ethereous flow.

7. Putting these things together, and considering the ether as essentially incompressible—on the strength of the Cavendish electric experiment, the facts of gravitation, and the general idea of a connecting continuous medium—the author reckons that to deal with the ether dynamically it must be treated as having a density of the order 10^{12} grammes per cubic centimetre.

8. The ether is perfectly penetrable by matter without resistance; the absence of friction being specially tested by my experiment of the revolving steel discs; and particles can move through it at nearly the velocity of light, as shown by Rutherford. Consequently reaction between ether and matter is an inertia term, and not a viscosity term. It behaves therefore like a perfect fluid—a perfect liquid of enormous density and zero viscosity.

9. The existence of transverse waves in the interior of a fluid can only be explained on gyrostatic principles, *i.e.*, in terms of kinetic or rotational elasticity. And the internal circulatory speed of the intrinsic motion of such a fluid must be comparable with the velocity with which such waves are transmitted.

10. Putting these things together, it follows that the intrinsic or constitutional vortex energy of the ether must be of the order 10^{33} ergs per cubic centimetre.

Conclusion.—Thus every cubic millimetre of the universal ether of space must possess the equivalent of a thousand tons, and every part of it must be squirming internally with the velocity of light.

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5. *An Electrical Experiment for illustrating the Two Modes of Condensation of Moisture on Solid Surfaces. By* Professor F. T. Trouton, *F.R.S.*

Experiment has shown, what might perhaps have been anticipated from theoretical considerations, that there are two possible modes in which condensed water vapour can exist on solid surfaces and be in equilibrium with a given vapour pressure.

After which of these modes condensation will take place on bringing a surface into a moist atmosphere depends on its previous history. If the surface has been dried at a high temperature, with the aid of phosphorus pentoxide, the amount of moisture is relatively small, and is said to be of the *a* type; but if the drying has been effected at only ordinary temperatures, there is considerably greater condensation, called of the *b* type. This is attributed to there being in the latter case still some of the liquid on the surface, affording examples of nuclei for liquid condensation of the *b* type, while in the former case the condensation is more analogous to the supersaturated state, which can occur when a vapour is compressed along an isothermal in the absence of the nuclei necessary for condensation.

When a completely dried surface of glass is placed in an atmosphere of which the moisture is gradually increased from zero, the course of events is as follows: At first very little moisture condenses compared with that which takes place if the drying has been incomplete, but on reaching a certain critical vapour pressure the condensation is very rapid, and is now of the *b* type.

The electrical conductivity of these two types of condensed surface layers is

very different. A comparative experiment was made in which two rods of glass were laid from earth to the knobs of two electroscopes, passed up for the purpose into a vessel in which the percentage of moisture could be changed at will. One of these rods was dried by heating, while the other was not. As the percentage of moisture was increased the air-dried rod was observed gradually to acquire considerable conducting powers, but the other rod did not conduct until the critical pressure was reached, when it did so relatively suddenly. The critical pressure for glass is roughly 50 per cent. saturation.

In the case of shellac the critical pressure was found to be above 90 per cent. A simple experiment illustrating the two modes of condensation was exhibited. An electroscope with shellac insulation was covered by a bell jar which had been previously held for a moment over a Bunsen flame to acquire a damp atmosphere. No discharge occurred. The experiment was now repeated, but the shellac was first moistened and then dried with a cloth, so as to again insulate. On the electroscope being covered by the bell jar immediate discharge took place, even though in the meantime the air in the jar must have somewhat dried. This was the *b* or conducting type of condensation. On now melting the surface of the shellac so as completely to dry it, the surface was found to have reverted to the condition in which the *a* type of condensation is deposited.

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6. *On a Theoretical Method of attempting to detect Relative Motion between the Ether and the Earth.* *By* A. O. RANKINE.

The explanation which has been suggested to account for the negative results in experiments so far made is that the distance between two points in a body is shorter when the line joining them is parallel to the drift than when the line is perpendicular to it, and this by just the necessary amount to produce exact compensation. If δl is the increase in a length l in changing from a direction parallel to a direction perpendicular to the drift, then for exact compensation $\frac{\delta l}{l} = \frac{1}{2}\beta^2$, where β is the ratio of the velocity of the drift to the velocity of light. The method about to be described is based on the assumption that this change does exist.

Imagine two particles, each of mass m, one at each end of a massless bar of length $2r$. Let it be suspended in a horizontal position by a vertical wire through its mid-point. The moment of inertia of the system about a vertical axis through the mid-point is $2mr^2$, and the time period of an oscillation is given by $T^2 = Kmr^2$, where K is a constant depending only on the elastic properties of the wire. Let this time period be determined for a small oscillation, the equilibrium position of the length of the bar being parallel to the drift of the ether which is supposed horizontal.

Now attach the bar to the wire perpendicularly to its original direction. The wire itself will be in precisely the same position relative to the drift as before, but the bar is now perpendicular to the drift instead of parallel to it. We therefore expect an increase in length, and, supposing no other factor to change, a corresponding increase in the time period. From the above equation

$$T\delta T = Kmr\delta r$$

whence

$$\frac{\delta T}{T} = \frac{\delta r}{r} = \frac{1}{2}\beta^2.$$

Unfortunately this calculated change of time period is far too small to be detected practically, but it is interesting to regard the experiment from another point of view. It has been affirmed that no experiment is devisable which will yield a positive result owing to the entry of a compensating factor. If this be true, then no change of time period would take place in the above experiment, and it becomes necessary to seek for the compensating factor. The only possibilities are that K or m, or both, change. Of these K is excluded because, as we have

seen, the wire is in precisely the same position relative to the drift in both cases, and we are therefore justified in assuming that its elastic properties remain unaltered. Hence we are driven to the conclusion that equality of time periods could only be effected by a change of the correct amount in m. The moment of inertia would be the same in the two cases; that is,

$$mr^2 = \text{const.}$$

$$\text{Hence } 2mr\delta r + r^2\delta m = 0$$

$$\text{or } \quad \frac{\delta m}{m} = -2\frac{\delta r}{r} = -\beta^2$$

i.e., the necessary relative change in mass is double the relative change in length. Now, in the first case (*i.e.*, when the length of the bar is parallel to the drift), the particle is executing vibrations in a direction perpendicular to the drift, and, in the second case, it is moving parallel to the drift. In the second case the mass is less than in the first, and in order to account for equality of time periods it is necessary to suppose that the mass of a particle is greater when moving perpendicularly to the ether drift than when moving parallel to it by an amount β^2 times the mass of the particle.

It will be interesting to examine whether or not this result is in accordance with the values which have been calculated for the transverse and longitudinal masses of a moving electron. If m_l is the longitudinal mass and m_t the transverse mass, the above reasoning leads to

$$\frac{m_t}{m_l} = 1 + \beta^2.$$

On referring to Lorentz's calculation we find

$$\frac{m_t}{m_l} = \frac{(1-\beta^2)^{-\frac{1}{2}}}{(1-\beta^2)^{-\frac{3}{2}}} = 1 - \beta^2 ;$$

and from Abraham's calculations we obtain

$$\frac{m_t}{m_l} = \frac{1 + \frac{2}{5}\beta^2}{1 + \frac{6}{5}\beta^2} = 1 - \frac{4}{5}\beta^2$$

in both cases neglecting powers of β higher than the second. In both cases the transverse mass is found to be less than the longitudinal mass, and not greater, as required for a negative result in the above experiment. In these circumstances it is apparent that either these theories of transverse and longitudinal mass do not adequately represent the physical facts, or the experiment suggested in this paper is one which would, if practicable, yield a *positive* result.

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7. *On the Nature of Ionisation.*[1] *By* Professor H. E. ARMSTRONG, *F.R.S.*

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8. *Note on the Echelon Spectroscope and the Resolution of the Green Mercury Line.* *By* H. STANSFIELD.

An echelon spectroscope constructed by Messrs. Adam Hilger for Professor Schuster was described. Photographs of the green mercury line obtained with the instrument showed all the known components of the green line and a number of fainter components which had not previously been described.

Results obtained recently by different observers with echelon spectroscopes showed good agreement amongst themselves, and agreed with the values for three

[1] See the *Electrician*, August 9, 1907.

of the component lines obtained by Michelson by the analysis of the visibility curves for the interference fringes observed in his interferometer.

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9. *The Production and Origin of Radium. By* Professor E. Rutherford, *F.R.S.*

The results of experiments were described on the growth of radium observed in solutions of actinium. By suitable chemical treatment a solution of actinium was obtained which showed only a minute fraction of the growth of radium normally observed. No evidence was observed that the active deposit of actinium changed directly into radium. It was shown that the results were most simply explained by supposing that there exists in actinium a new substance of slow rate of change which is transformed into radium. This substance differs in chemical properties from actinium, and can be separated from it by suitable chemical methods. It was pointed out that this new substance may prove to be the intermediate product of slow change between uranium and radium. There was no direct evidence that actinium itself was the true parent of radium.

Further experiments are in progress to endeavour to isolate this new substance in order to examine its chemical and radioactive properties.

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10. *The Effect of High Temperature on the Activity of the Products of Radium. By* Professor E. Rutherford, *F.R.S., and* J. E. Petavel, *F.R.S.*

Bronson has shown that the activity of the products of radium is not appreciably altered by exposure to a temperature of 1600° C. On the other hand, Makower, working with the active deposit of radium, found that there was a small decrease of its activity, measured by the β and γ rays, when exposed for some time to a temperature of about 1100° C. The experiments of Schuster and of Eve have shown that the highest obtainable pressures have no influence on the activity of radium.

In the present experiments the emanation from about four milligrams of radium bromide was momentarily exposed to the influence of the very high temperature produced by the explosion of cordite in a closed steel bomb. The bomb used in these experiments was constructed by Mr. Petavel, and had been used by him in previous experiments on the pressures developed during explosions. The bomb was a complete sphere of mild steel, about 4 inches internal diameter and about 2 inches thick. About forty-six grains of cordite were placed in the bomb, and after exhaustion the emanation was introduced. About four hours later the emanation is in equilibrium with its products, and the activity due to the γ rays, which passed through the bomb, was observed by means of an electroscope placed outside the bomb. The cordite was fired electrically, and observations were made of any change of activity. By running the electroscope *during* the explosion, it was found that no sudden burst of activity occurred, showing conclusively that the normal rate of disintegration of the product, radium C, was not much altered by this process. Three experiments were made with equal weights of cordite, but of different diameter, in order to vary the suddenness of the explosion. In every case the activity measured by the γ rays was found to have decreased about 9 per cent. after the explosion. The activity gradually rose again, reaching nearly the equilibrium value after three hours. A special experiment showed that the rate of change of the emanation itself was not altered by the explosion.

The maximum pressure of the gases during the explosion was about 1200 atmospheres, and the maximum temperature certainly not lower than 2500° C.

The change of activity produced by the explosion may be due either to a sudden alteration of the distribution of the active deposit or to a change in the amount or period of the products, radium B and radium C. Since the active deposit of

radium is volatilised at about 1200° C., it would be rendered gaseous by the high temperature of the explosion, and redeposited when it cooled. Since the bomb was exactly spherical, a change of distribution of the active deposit does not appear very probable. In one experiment two electroscopes were used, one by the side of the bomb and the other underneath it. Both showed about an equal decrease of activity.

The experiments recorded here are preliminary, and it is intended to examine still further whether there is a real change of activity of radium products by the action of the high temperature.

11. *On a Freehand Potential Method.* *By* L. F. Richardson.

This paper described a graphic method for obtaining a vector function of position, which function shall satisfy given conditions over a boundary and be irrotational and non-divergent everywhere within that boundary.

In contrast to the usual methods, using Fourier series, Bessel functions, spherical or other harmonics, this is very simple. All one has to do is to imitate freehand the characteristic common properties of the diagram of intersecting stream surfaces and equi-potentials as given by Maxwell, Lamb, Hele-Shaw, and others.

Many people have doubtless used such a method in a rough way, but no one seems to have realised the accuracy and power of which it is capable. As far as the author has tested it, it will give an accuracy of 1 or 2 per cent. of the range considered, which is sufficient for many purposes.

This method can only be applied when the potential is constant along each line of a limited number of families of lines in space. Of these the chief are (1) parallel straight lines; (2) circles in planes normal to, and with their centres on, a common axis; (3) radii from a point; (4) the normals to the surfaces of a thin shell of any shape; (5) screw-threads of common and constant pitch about a common axis. But within these types the freehand method far surpasses analysis in its power of dealing with various forms of surface.

It will also deal with varying conductivity. It is hoped that it may be of use to engineers.

TUESDAY, AUGUST 6.

The following Papers and Reports were read :—

1. *Examples of the Modern Methods of treating Observations.* *By* W. Palin Elderton.

This communication dealt with the application of recognised statistical processes to meteorological statistics. The terms *mean, median,* and *mode* were defined, and the methods of calculating their values given, with examples from rainfall statistics. The '*method of moments*' was described, and as an application a parabolic curve was fitted to statistics of rainfall in the east of England. The *standard deviation* was then explained, and it was pointed out that this function measures the way the observations are scattered about their mean. The importance of calculating a 'standard deviation' or a 'probable error' corresponding with means was then insisted on; the mere statement of a mean is statistically insufficient and of no use for comparative purposes until we know what deviations from the calculated value may arise.

The remainder of the communication dealt with correlation. The coefficient of correlation was first explained, and it was shown how it can be calculated. The rainfall in the east of England was compared with that in the north of Scotland and in the Channel Islands: in the former case the coefficient of correlation is very small, and about equal to its probable error, so that we cannot conclude that there is any correlation; but in the latter case the coefficient is found to be $\cdot 374 \pm \cdot 065$,

and indicates that there is a distinct connection between the rainfall in the east of England and that in the Channel Islands. Another example taken was rainfall and typhoid cases in Surrey districts, the water-supply of which is obtained from river sources. The coefficient of correlation is 0·116, with a probable error of 0·073, so that it is impossible to assert definitely that there is any relation between rainfall and typhoid—at any rate on the evidence afforded by these statistics. Reference was made to a paper on barometric heights by Professor Karl Pearson, F.R.S., and Dr. Alice Lee, and to the use of the coefficient of correlation by Dr. Gilbert T. Walker, F.R.S., in his interesting memoranda on the meteorology of India.

The author concluded with an appeal for the more scientific treatment of statistics by modern methods.

2. *On the Use of Calcite in Spectroscopy.* *By* Professor W. M. Hicks, *F.R.S.*

The advantages of the large dispersion in the ultra-violet produced by calcite are so great that it may be interesting to describe the method which the author has used to get rid of the double refraction which shows itself at a short distance from the ray experiencing minimum deviation. The method is based on suppressing one of the rays by using polarised light. With a parallel beam, vibrating either horizontally or vertically, the transmitted light belongs respectively to the extraordinary or the ordinary ray. The angle of incidence is not far from the polarising angle; consequently the horizontal vibrations (polarised perpendicular to plane of incidence) are transmitted in larger proportion than the other. The spectrograph in question had one calcite prism of 60° and two half-prisms of 30° each. The calculated intensities of the transmitted light in the two polarised rays come out to be in the ratios 2·35, 3·05, 4·67 respectively for minimum deviations for the rays 5600, 3000, and 2500 — the horizontal vibration being the stronger—whilst the corresponding ratios at points where the doubling is pronounced are 2·44, 3·31, and 5·03. It is therefore preferable to polarise the light in a vertical plane.. It is impossible, however, to use polarised light with a quartz lens in the collimator, since the rotations produced by the different thicknesses of the lens give a mixed beam when it falls on the prism. To get over this difficulty a composite lens was made, of equal plane convex lenses, one of right-handed and the other of left-handed quartz. The spectra obtained are then very satisfactory. As polariser a Nicol can be used for light down to about 3000, but between 3000 and 2950 the thin layer of Canada balsam completely absorbs the light. For wave lengths shorter than this a small Foucault, fixed like a comparison prism, was used, and this was quite satisfactory down to 2300, at about which the calcite begins to absorb the light. Near this, however, the ordinary ray has only about one-fifth the intensity of the extraordinary, and it is scarcely necessary to use any polarising arrangement at all.

The whole spectrum from 6000 to 2300 covers about 30°. Negatives were shown illustrating (1) the doubling and its removal by polarisation; (2) the relative intensities of each component; and (3) the almost complete effacement of the ordinary ray component for wave-lengths below 2500.

Department of Mathematics.

The following Papers and Reports were read:—

1. *The Introduction of the Idea of Infinity.* *By* W. H. Young, *Sc.D.*, *F.R.S.*

It was pointed out that there are three methods of treating mathematics, viz., the logical, the formal, and the practical methods, and it was urged that the formal method had had for many years more than its share of attention in

England. The author held that the importance of the practical method was now being generally recognised, but that there was considerable danger of the logical method being neglected, and in this way some of the best minds in the country being lost to mathematics.

The author explained in some detail how the idea of infinity naturally presented itself at an early stage in a boy's education, and how it might and should be elucidated. In this connection the importance of the concept of *limiting point* was referred to, and illustrated by the fact that this concept was involved in a precise definition of the centre of mass of a heterogeneous body.

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2. *The Teaching of the Elements of Analysis. By* C. O. TUCKEY.

How must the teaching of the elements of analysis be modified in view of the early stage at which the calculus is now reached?

The main defects (which we must hope to avoid) of the now usual course are—

(i) The initial elaborate discussion of convergence, which ignores the lesson from history, that only as much of this theory should be given as is shown to be necessary by examples of false results deduced by plausible reasoning.

(ii) The apparent lack of object in discussing infinite series.

(iii) The abrupt introduction of the exponential function.

(iv) The unnecessary difficulty of the proofs of the series for $\sin x$ and $\cos x$.

(v) The proceeding from difficult to easy by taking first the rigorous proofs of the expansions and later the easy method of obtaining the series by the calculus, their existence being assumed.

The course advocated is based on the calculus; the necessity of commencing it before differentiating a^x, and other reasons, point to the convenience of beginning it when the differentiation of $\cos x$ and $\sin x$ is known.

The numerical calculation of $\sin x$, $\cos x$, and also $\log x$ is put forward as the object of the course, and it is explained that series are obtained for these functions.

The series for $(a+x)^n$, n integral, and $\frac{1}{1-x}$ being known to the student, the calculus method of obtaining by repeated differentiation the coefficients of a series (assumed to exist) is illustrated by these known series.

Then the binomial series for fractional and negative powers are worked out in the same way.

Taking series for $(a-x)^{-n}$, say, and putting $a>x$, shows necessity for discussion of convergence, which is then taken in hand and proofs given that—

(i) Σu_n where $\mathrm{Lt}\ \frac{u_{n+1}}{u_n} < 1$ is convergent (comparison with G.P. used);

(ii) $u_1 - u_2 + u_3 - \ldots$ is convergent if $u_1 > u_2 > u_3 > \ldots$

An example from partial fractions, taking

$$\frac{x^3}{1-x^2} = \frac{A}{1-x} + \frac{B}{1+x},$$

shows that the fact that no hitch occurs in finding the coefficients must not be regarded as a proof of these series, and shows the necessity for rigorous proofs later on.

The series for $\sin x$ and $\cos x$ are obtained by the calculus method (existence assumed), and considerable practice is given with these series and the various forms of the binomial series before proceeding to the next stage, viz., the exponential function.

The importance of a function obeying the law $\frac{dy}{dx} = kx$, the 'compound interest' law, is emphasised by instances—compound interest, and examples from physics

such as the cooling of a hot body—and it is shown by attempting to differentiate a^x that a^x obeys this law.

The solution in series of this equation is obtained, viz., $y = A \exp(kx)$, and we proceed to study the function $\exp(x)$.

As $a^x . a^y = a^{x+y}$ is the defining property of a^x for other than integral indices, we discuss the product $\exp x . \exp y$ [proving that multiplication of such series is legitimate] and find it equals $\exp(x+y)$.

Hence in the usual way we deduce that $\exp(x) = \{\exp(1)\}^x \equiv e^x$.

This is the first 'proof' for the expansion of a function in an infinite series (except the G.P.) that the student will have met. It is taken before the corresponding proof for the general binomial series as being easier; but this should now be worked out on similar lines, and the deduction of the exponential from the binomial series sketched roughly (without rigour in the details being attempted).

After practice with exponential functions, the series for $\log(1+x)$ is reached; first this is worked out by the method of the calculus, and made familiar to the student; then the strict proof is attempted.

Here two proofs are sketched: integration of the series for $\frac{1}{1+x}$, and rearrangement of the series for $(1+x)^y$ and comparison with that for $e^{y\log(1+x)}$. Either of these proofs requires further work in the convergence of series to be tackled—the first 'uniform' convergence, the second the convergence of double series, and perhaps it would be well to omit these proofs except for the best boys.

To give the strict proof of the series for $\sin x$ and $\cos x$, we must suppose a course of work on complex numbers to be taken, either *pari passu* with the course that has been sketched or at this stage.

We then proceed with complex indices defining a^{c+id} as $\exp\{(c+id)\log a$ and find the value of $\exp(ix)$ as follows:—

(i) $\text{Mod} \exp(ix) = \sqrt{\{\exp(ix) . \exp(-ix)\}} = \sqrt{\{\exp(0)\}} = 1$

$\therefore$ a value of θ can be found such that $\exp(ix) = \cos\theta + i\sin\theta$

(ii) $\because$ differentiating $\exp(ix)idx = (-\sin\theta + i\cos\theta)d\theta = (\cos\theta + i\sin\theta)id\theta$

$$\therefore dx = d\theta$$
$$\therefore x = \theta + \text{constant}$$

(iii) Putting $\theta = 0$ in $\exp(i\theta + k) = \cos\theta + i\sin\theta$ we see that $k = 2in\pi$

$\therefore \cos\theta + i\sin\theta = \exp(i\theta)$, which gives the series for $\cos\theta$ and $\sin\theta$.[1]

If we now show that log (complex number) = log (modulus) + i (amplitude) and deduce the series for $\tan^{-1}x$ from that for $\log(1+z)$, we shall have completed the usual course on series, with the exception of Taylor's series for $f(x+h)$, which should be discussed at the end of the course, as a generalisation of the previous work, the remainder after the nth term of the series being carefully investigated.

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3. *On Models of Three-dimensional Sections of Regular Hypersolids in Space of Four Dimensions.* By Mrs. A. Boole Stott.

After giving an idea of the four different kinds of axes of a regular four-dimensional polytope, and having explained in what manner any of these six polytopes may be intersected by a range of parallel spaces normal to any of these axes, Mrs. Stott exhibited the different kinds of sections that may be obtained by models of cardboard differently coloured, so as to show the position of the different regions of bounding bodies with respect to the central axis. She also exhibited models illustrating the space-filling properties of a three-dimensional section of any set of regular polytopes filling-space of four dimensions. Also

[1] This is a modification of a proof given by Stolz and Gueimer, and is due to my late pupil, Mr. McCleland.

models illustrating the rotation of a four-dimensional body about a plane by the sections of it, with a space containing that plane. Professor Schoute showed some lantern-slides in connection with the subject.

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4. *Models of Three Developable Surfaces.* *By* Professor SCHOUTE.

The author showed three models of developable surfaces in connection with the equations

$$u^3+3u^2x+3uy+z=0,$$
$$u^4+6u^2x+4uy+z=0,$$
$$u^6-15u^4+15u^2x+6uy+z=0.$$

He moreover indicated that, if only the equation

$$u^n+A_1u^{n-1}+A_2u^{n-2}+\ \ldots\ +A_{n-1}u+A_n=0$$

has all its roots positive, the equation

$$u^{2n}+A_1u^{2n-2}+A_2u^{2n-4}+\ \ldots\ +A_{n-2}u^4+xu^2+yu+z=0$$

may represent all possible cases of $2n$, $2n-2$, . . . 2, 0 real roots, and that by means of the double curve the corresponding developable surface really must, and will, divide space into $n+1$ regions.

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5. *On an Unrecorded and Remarkable Feature in the Splash of a Drop.* *By* Professor A. M. WORTHINGTON, *F.R.S.*

The object of this paper was to call attention to the fact that the impact of a drop excavates a perfectly spherical hollow, which reaches its greatest depth at apparently the same time that the water thrown up attains its maximum height. The volume of this spherical pit is enormously greater than the volume of the drop, being 360 times as great with a height of fall of 177 cm., forty-four times as great with a height of fall of 40 cm. The spherical hollow is lined by the original liquid of the drop in the form of a thin layer. The centre of the sphere descends as the radius increases till a maximum depth is attained.

The phenomenon appears to be one in which surface tension plays but a small part, and should be capable of hydrodynamical treatment.

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6. *A Property of Abelian Groups.* *By* HAROLD HILTON.

Let $u_1, u_2, \ldots, u_m$; $t_1, t_2, \ldots, t_m$ be two sets of positive integers or zeros such that $u_m+u_{m-1}+\ldots+u_s \geqslant t_m+t_{m-1}+\ldots+t_s$ for all values of s between 1 and m inclusive.

Denote $u_m+u_{m-1}+\ldots+u_s-t_m-t_{m-1}-\ldots-t_{s+1}$ by $k_s (k_m=u_m)$, $t_m+t_{m-1}+\ldots+t_1$ by t, $k_m+k_{m-1}+\ldots+k_1$ by k.

We shall write $f(n)$ for $(p^n-1)(p^{n-1}-1)\ldots(p^2-1)(p-1)$ where p is a prime, and suppose $f(0)=1$.

Take the coefficient of

$$y^{t_1} \text{ in } (1+py)(1+p^2y)\ \ldots\ (1+p^{k_1}y), \text{ of}$$
$$y^{t_2} \text{ in } (1+p^{k_1+1}y)(1+p^{k_1+2}y)\ \ldots\ (1+p^{k_1+k_2}y), \text{ of}$$
$$y^{t_3} \text{ in } (1+p^{k_1+k_2+1}y)\ \ldots\ (1+p^{k_1+k_2+k_3}y),\ \ldots, \text{ of}$$
$$y^{t_m} \text{ in } (1+p^{k_1+\ldots+k_{m-1}+1}y)\ \ldots\ (1+p^{k_1+\ldots+k_{m-1}+k_m}y),$$

and form their product P. We thus obtain part of the coefficient of

$$y^t \text{ in } (1+py)(1+p^2y)\ \ldots\ (1+p^{k_1+\ldots+k_m}y);$$

the total coefficient $\frac{f(k)}{f(t).f(k-t)}.p^{\frac{1}{2}t(t+1)}$ being obtained by giving $t_1, t_2, \ldots, t_m$ all possible positive integral or zero values consistent with $t_m + t_{m-1} + \ldots + t_1 = t$, and adding the corresponding values of P.

$$\text{Now } P = \frac{f(k_1)}{f(t_1).f(k_1-t_1)} \times \frac{f(k_2)}{f(t_2).f(k_2-t_2)} \times \ldots \times \frac{f(k_m)}{f(t_m).f(k_m-t_m)} \times p^e,$$

where
$$\begin{aligned} e &= \tfrac{1}{2}t_1(t_1+1) + \tfrac{1}{2}t_2(t_2+1) + \ldots + \tfrac{1}{2}t_m(t_m+1) + t_2k_1 + t_3(k_1+k_2) \\ &\quad + \ldots + t_m(k_1+k_2+\ldots+k_{m-1}) \\ &= \tfrac{1}{2}t(t+1) + (u_1-t_1)(t-t_1) + (u_2-t_2)(2t-t_2-2t_1) \\ &\quad + (u_3-t_3)(3t-t_3-2t_2-3t_1) + \ldots \end{aligned}$$

Hence $P = Np^{\frac{1}{2}t(t+1)}$; where N is the number of subgroups with t_m invariants m, t_{m-1} invariants $m-1, \ldots, t_1$ invariants 1 in an Abelian group of order $p^{mu_m+(m-1)u_{m-1}+\ldots+u_1}$ with u_m invariants m, u_{m-1} invariants $m-1, \ldots, u_1$ invariants 1.[1] The index of each subgroup is p^{k-t}; for $k-t = mu_m + (m-1)u_{m-1} + \ldots + u_1 - mt_m - (m-1)t_{m-1} - \ldots - t_1$.

Now the equations $u_m + u_{m-1} + \ldots + u_s - t_m - t_{m-1} - \ldots - t_{s+1} = k$ may be put in the form $u_s - t_{s+1} = k_s - k_{s+1} (u_m = k_m)$. Hence if we take every abstract Abelian group whose order is a power of p with no invariant greater than m, and find every subgroup with t invariants such that (for all values of s lying between 1 and m inclusive) the number of invariants $s+1$ of the subgroup differs from the number of invariants s of the group by a given integer $l_s(=k_s-k_{s+1})$, the number of subgroups so obtained is $\frac{f(k)}{f(t).f(k-t)}$, where p^{k-t} is the index of each subgroup.

If we take every possible abstract Abelian group with no invariant greater than m, and find for each group all subgroups of index p^{k-t} with t invariants which possess no more invariants $s+1$ than the group possesses invariants $s(s=1, 2, \ldots, m)$, the total number of subgroups so obtained is $\frac{f(k)}{f(t).f(k-t)} a$; where a_k is the coefficient of y^k in the expansion of $\frac{1}{(1-y)(1-y^2)\ \ldots\ (1-y^m)}$. For a is the number of ways of selecting positive or zero integers such that $l_1 + 2l_2 + \ldots + ml_m = k$.

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7. *Factorisation of the Pellian Terms (τ_n, v_n, &c.)* *By* Lieut.-Col. Allan Cunningham, *R.E.*

Let $\tau_n^2 - Dv_n^2 = +1$, and—(when possible)—let one of

$$\left.\begin{matrix} \tau'^2_n - Dv'^2_n = -1, & D_1 t_n^2 - D_2 v_n^2 = \pm 1 \\ \xi_n^2 - D\eta_n^2 = \pm 2, & D_1 x_n^2 - D_2 y_n^2 = \pm 2 \end{matrix}\right\} \text{where } D_1 D_2 = D$$

Taking $= 1, 2, 3, .—.$ gives the successive solutions of above.

(i) Then $v_{2n} = 2\tau_n v_n$ always
$v_{2n-1} = 2T_nU_n$ or $= X_nY_n$ always

where $\left.\begin{matrix}(T_n, U_n) = (\tau'_n, v'_n) \text{ or } t_n, u_n) \\ (X_n, Y_n) = (\xi_n, \eta_n) \text{ or } (x_n, y_n)\end{matrix}\right\}$ formed by same rule as τ_n, v_n, *i.e.*, $\tau_{n+1} = 2\tau_1 . \tau_n - \tau_{n-1}$, when $n > 2$.

Also $\tau_{2n-1} = (2v'_n - 1)(2v'_n + 1)$, when $D = 2$.

(ii) As to 2^{ic} forms: $v'_n = a^2 + b^2$, $\tau_{2n} = 2\tau_n^2 - 1$ always.

and when $D = 2$, $\tau'_n = e^2 - 2f^2$, $v'_n = a^2 + b^2$, $\tau_n = c^2 + 2d^2$ and τ_{2n} has the three 2^{ic} forms.

[1] *Proc. Lond. Math. Soc.*, 2, v. p. 3.

$$\left.\begin{array}{l}\text{(iii) Generally } \tau_{2n-1} \equiv 0 \pmod{\tau_1},\ v_n \equiv 0 \pmod{v_1}, \\ T_n,\ U_n,\ X_n,\ Y_n \equiv 0 \ (\text{mod } T_1,\ U_1,\ X_1,\ Y_1 \text{ respectively})\end{array}\right\} \text{so are usually composite.}$$

τ_n, v_n are factors of v_{2n} and recur in τ_{n+2mn}, v_{n+2mn} respectively, and both recur in v_{2mn}, [$m=1, 2, 3,$ &c.].

(T_n, U_n), or (X_n, Y_n) are factors of v_{2n-1} and recur in ($T_{n+\mu}$, $U_{n+\mu}$), ($X_{n+\mu}$, $Y_{n+\mu}$), respectively, and also paired together in v_μ, where $\mu=(2n-1)m$: and the same rules apply to the prime factors (p) of τ_n, v_n, T_n, U_n, X_n, Y_n.

(iv) As to division by a prime (p):—

1°. If $D=p$, or $\equiv 0 \pmod{p}$, then $v_p \equiv 0 \pmod{p}$.
$\tau_{2n} \equiv +1 \pmod{p}$, $\tau_{2n+1} \equiv \tau_1$, and $\tau_1 \equiv \pm 1 \pmod{p}$.

2°. If $D \not\equiv 0 \pmod{p}$, then $v_r \equiv 0 \pmod{p}$ requires that $\frac{1}{2}\left\{p-\left(\frac{D}{p}\right)\right\} \equiv 0 \pmod{r}$ as a *preliminary* condition.

If q be *prime*, and $p=2q\varpi+1$, and $\frac{1}{2}\left\{p-\left(\frac{D}{p}\right)\right\} \equiv 0 \pmod{q}$, then $v^q \equiv 0 \pmod{p}$.

In both 1°, 2°; if $v_{2n} \equiv 0$ mod p, then one of τ_n, $v_n \equiv 0 \pmod{p}$; and, if $v_{2n-1} \equiv 0 \pmod{p}$, then one of T_n, U_n or one of X_n, $Y_n \equiv 0 \pmod{p}$. The 2^{ic} forms given above often suffice (especially when $D=2$) to show which of τ_n, v_n, T_n, U_n, X_n, Y_n, can $\equiv 0 \pmod{p}$.

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8. *Report on Bessel Functions.*—See Reports, p. 94.

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9. *Report on the Teaching of Elementary Mechanics.*—See Reports, p. 97.

Department of Astronomy and Cosmical Physics.

The following Papers and Reports were read:—

1. *The Variation of Latitude.* *By* Dr. O. Backlund.

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2. *On some recent Developments of the Method of Forecasting by means of Synoptic Charts.* *By* W. N. Shaw, *LL.D., Sc.D., F.R.S.*

The method of forecasting based upon the movements of cyclonic depressions and anticyclonic areas has now been in use for some thirty years, and may be called the classical method. It deals with the relations of pressure, wind, and other meteorological elements to *centres* of low pressure and high pressure respectively, and may be described briefly as consisting in detecting the existence of a cyclonic depression, locating its centre, and anticipating its path.

The reference of all the phenomena to a centre tends towards the smoothing of the isobars, as far as possible, into curves, with the minima as centres, and to dealing with the characteristics of an average or typical depression as generally applicable to the individual cases. Observations of pressure and wind which show marked deviation from the conventional type are apt to be regarded as due to errors of observation, or in transmission, or to local conditions of no general importance.

That this method gives a fairly satisfactory 'first approximation' to the solution of the question of forecasting is evident from the fact that of the evening forecasts of the Meteorological Office based upon it 61 per cent. were classed as completely successful for the year 1906 and 56 per cent. for the past ten years, while 30 per cent. and 29 per cent. respectively were partially successful.

At the same time, the margin of failures and incomplete successes is sufficiently

large to show that some closer approximation is desirable, and a reconsideration of the process of dealing with cyclonic depressions as centrical distributions is a first step in that direction.

The 'average' cyclonic depression is certainly not the most frequent—possibly it has never existed—and the typical cyclonic depression is of very rare occurrence. Further, it is only for the distribution of pressure, and to a certain extent for winds, that any centrical symmetry can be claimed. Temperature, clouds, and rainfall have no symmetrical distribution with regard to the barometric minima.

The classical method, indeed, has always recognised the existence of deviations from symmetry, and has regarded them as 'secondary depressions' with certain recognised consequences.

The report by M. B. Brunhes, Director of the Observatory of the Puy de Dôme, upon the results of the competition in weather forecasting in connection with the exhibition at Liège in 1905 has brought into prominence two methods which lay great stress upon the importance of the deviations from symmetry, and constitute, as M. Brunhes says, a definite step towards a second approximation in forecasts of weather by means of synoptic charts.

The two methods are by M. Durand Gréville, of Paris, and by M. Guilbert, of the Meteorological Society of Calvados, respectively. The paper gives an account of these two methods and illustrations of them by means of charts specially constructed for the purpose.

M. Durand Gréville's contribution consists chiefly in recognising the existence of disturbances of the smooth course of the isobars surrounding a cyclonic centre extending in a long narrow band from the centre or from near thereto. The band consists generally of an exaggeration of the fall of pressure along the front of the band (*couloir de grain*) and a more rapid rise following it (*ruban de grain*), and then a resumption of the regular march of the isobars until a second *ligne de grain* arrives. While the *ruban de grain* is sweeping over a district in a manner similar to the march of a wave-front, changes in the direction and force of the wind, and rainfall, occur with varying degrees of intensity along the line. In some localities, where conditions are favourable, line-squalls or thunderstorms are developed. In order to exhibit the existence of these *lignes de grain* M. Durand Gréville advocates the drawing of isobars for intervals of 1 millimetre instead of for 5 millimetres, as is usual in Continental charts.

The characteristics of a *ligne de grain* are illustrated by the diagrams prepared by Mr. Lempfort for his paper on the line-squall of February 8, 1906, read before the Royal Meteorological Society in May 1906; and the special maps prepared for further illustration are those for June 22–23, 1900, November 1–2, 1893, and December 7–8, 1899. In these the pressure is expressed in degrees of pressure (2000 dynes per sq. cm.) and isobars drawn for intervals of one degree of pressure (1·5 mm.), as explained to the Association at Cambridge in 1904. Maps were constructed on a similar plan to illustrate M. Guilbert's contribution for August 31–September 1, 1905, September 4–5, 1905, and February 19–20–21, 1892.

M. Guilbert's method depends upon the comparison of the actual winds, as recorded on the map, with ideal or normal winds as computed from the distance apart of the consecutive isobars.

The method of calculation of winds employed in the Meteorological Office in accordance with the formula

$$\gamma = \Delta(2\omega V \sin\lambda \pm V^2 \cot\rho / R)$$

is considered, and M. Guilbert's estimate of normal winds compared therewith. Examples are given in the maps already specified of M. Guilbert's application of the vector-deviation from the normal winds to determine the localities of the rise and fall of the barometer in the ensuing twenty-four hours.

M. Guilbert's method is summarised by the statement that where the vector-deviation forms an anticyclonic system barometric fall is to be expected, and where the vector-deviation is cyclonic a rise of the barometer is to be expected.

3. *A Mountain Observatory in South India.* *By* C. MICHIE SMITH.

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4. *The Variability in Light of Mira Ceti and the Temperature of Sunspots.* *By* Rev. A. L. CORTIE, *S.J.*, *F.R.A.S.*

The existence of a spectrum of bands in sun-spots has been recorded by observers since 1869, when they were first observed by Secchi. A fluted or banded spectrum is characteristic of chemical compounds. Hence the view enunciated by Young in 1872 that a fall of temperature over sun-spots allowed the formation of such compounds. Recent spectroscopic laboratory and observatory work at Mount Wilson and South Kensington has strengthened the probability of this view. Some of the bands in the red end of the spectrum are due, as Hale and Adams have shown, to titanium oxide, others in the green have been recently attributed to magnesium hydride by Fowler. The purport of the present paper is to adduce an argument in favour of the relatively low temperature of sun-spots, from the behaviour of the bands of titanium oxide in *o* Ceti, when the star is at two different temperature levels, represented by a whole magnitude in luminous power. At the maximum in 1897 the magnitude of the star was 3·0, at that of December 1906 it reached the brilliancy 2·0 mag. Two series of plates of the spectrum of the star were taken under precisely identical conditions of instrument and plate by Father Sidgreaves at Stonyhurst at the two periods. In 1897 fourteen bands were photographed between H_β and H_γ: these bands are much reduced in intensity in 1906, those with heads at λ 4757, 4803, and 4842 having entirely lost their winged appearance. Concomitant evidence of the greater temperature of the star in 1906 is furnished by the behaviour of the hydrogen lines. Not only is the whole series from H_β to H_σ present, with the exception of H_ϵ, covered by calcium absorption, but H_γ and H_δ are winged, presenting somewhat of the appearance of the hydrogen lines in the new stars Nova Aurigæ and Nova Persei. Again, there is a gradual darkening of the titanium-oxide bands in the spectra of stars from a solar star such as *a* Tauri of Type II., through *β* Andromedæ, *a* Orionis, *η* Geminorum, *β* Pegasi, to *a* Herculis and *o* Ceti; and in the transition from Type II. to Type III. Mira Ceti is further removed from the solar type than *a* Orionis or *a* Herculis, and the characteristic sun-spot lines of titanium and vanadium are more prominent in its line spectrum than even in the case of *a* Orionis. These facts furnish further links of similarity between the sun-spot spectrum and that of *o* Ceti. Hence, to sum up, the undoubted presence of the chief constituents of the line spectrum of sun-spots as intensified in stars of Type III.; the presence of the bands of titanium oxide, also recognised in sun-spots; the partial disappearance of some of these bands and the total disappearance of others when Mira Ceti attained a greater luminosity at maximum than is usual, and this too enhanced by a behaviour in the hydrogen lines akin to that observed in new stars; the substitution of a line for a banded spectrum in a series of stars on an ascending scale of temperature—these are all phenomena which when linked together point to the conclusion that the temperature of sun-spots is lower than that of the solar photosphere.

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5. *On a Method of improving the Constants of the Plates for the Astrographic Catalogue.* *By* Professor H. H. TURNER, *F.R.S.*

The centres of the plates for the Astrographic Catalogue in any one zone are at intervals of eight minutes apart near the equator and more elsewhere. Suppose we point the telescope to one of them and give an exposure of four minutes. Without disturbing the plate at all, we have now four minutes in which to set for the guiding star of the next region, pick it up, and commence (and finish) an exposure of four minutes to this new region at exactly the same hour-angle as before. Then we again have four minutes to pick up the next region, and the process may be continued indefinitely. When the plate is developed, a réseau

being impressed in the usual way, it will contain the brighter stars of all the regions to which exposure was made: and with a little care the stars of each region can be given sensibly the same réseau co-ordinates as on the separate plate S, already measured for the Catalogue. The superposition of several regions will give no trouble in measuring if the co-ordinates are called out from the existing measures (*e g.*, the measures already printed) by an assistant; and new measures made on the composite plate C will give, with very little work, the differences $C-S_1$ of scale value and orientation (I say nothing here of errors of centre, which are to be for the present neglected, though I am not without hopes of determining them also by photographing a fixed mark with each region) between the separate plate S_1 and the composite plate C. Now the constants of the separate plates, S_1, S_2, S_3, &c., have all been determined, though the determinations are rough, owing to the roughness of the meridian places and the small number of stars on each plate. Owing to this roughness, when we add the measured differences $(C-S_1)$ for any of the plate constants to the provisionally found S_1, we shall get values $C_1=(C-S_1)+S_1$, $C_2=(C-S_2)+S_2$, and so on, which are also rough, but the mean value C_0 of C_1, C_2, &c., will be a much better determination than any of its separate members; and we can now deduce from the well-determined C_0 and the measured differences $(C-S_1)$, $(C-S_2)$, &c., much better values of the constant in question for the individual plates. That for the first plate, for instance, will be $C_0-(C-S_1)$.

A correction to the orientation is required for precession between the epoch 1900·0 (for which the constants of S_1 were calculated) and the epoch at which C is taken; but this is a simple matter.

The method is being tried at Oxford—two composite plates of thirteen regions, each having been obtained and measured, and one of them reduced—and the results are satisfactory so far. But the work is not yet complete. If successful, the method will be of value in reducing the amount of new meridian observation required.

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6. *On the Determination of Periodicity from a Broken Series of Maxima.* *By* Professor H. H. Turner, *F.R.S.*

By his work with the periodogram Professor Schuster has emphasised the fact that we must try all possible periods in a systematic manner if we would properly analyse a set of observations. Even when we seem to have already found the mean period (as, for instance, the eleven-year period in the case of sun-spots) systematic trial of other periods may give us unsuspected information. The labour is great, but there is no evading it.

The periodogram method is applicable only when the series of observations is regular and complete over a certain lapse of time. The sun-spot record is not absolutely complete, but it can be made so for practical purposes. This is not so in other cases, as, for instance, for the light curve of a variable like U Geminorum, which differs from the sun-spot record in two principal features.

(1) Observations near minimum are generally absent altogether and cannot be supplied; so that the record is essentially a record of maxima only.

(2) Even these are often lost from cloudy weather or other circumstances, so that the record is a broken one.

In these circumstances it is necessary to substitute for the regular Fourier analysis some other process by which a number characterising each tentative period can be obtained. The suggestion of this note is that, having obtained the epochs of maxima $E_1, E_2, E_3 \ldots E_m$, and having written down a series of theoretical epochs $E_0, E_0+2n, E_0+4n, E_0+6n$, &c., where $2n$ is a period to be tried, we should then form the differences of the observed epochs from the *nearest* theoretical epochs. Calling these differences $r_1, r_2, r_3 \ldots r_m$, we form—

(*a*) the algebraic mean $\dfrac{1}{m}(r_1+r_2+\cdots+r_m)$

(*b*) the sums of the squares $r_1^2+r_2^2+\cdots+r_m^2$.

Under certain conditions (b) should be a minimum when we have hit on a real periodicity. The conditions are made obvious by supposing the periodicity perfect and the observations without error, when by choosing E_0 properly, we can make all the residuals zero, and hence (b) will be zero. But if E_0 is not properly chosen, (b) will not be zero. Its greatest value will be mn^2 when all the observed maxima fall just midway between consecutive tabulated maxima. Hence the need for forming also the algebraic mean (a) which in the former case will be zero and in the latter will be mn. If (a) comes out sensibly different from zero, we must alter E_0 (in a manner which need not here be explained) until (a) is small enough.

When there is no periodicity near $2n$ the residuals will have indifferently any value from 0 to n, and (if n is an integral number of days) the sum of the squares of the residuals will approximate to $\frac{1}{6}mn(2n+1)$ or say $\frac{1}{3}mn^2$. When we get serious differences from this, it is worth while to investigate further.

The method is being applied to the case of U Geminorum, and some interesting results obtained.

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7. *An Analytical Study of the Meteorological Observations made at the Glossop Moor Kite Station during the Session* 1906–1907. *By* MARGARET WHITE, T. V. PRING, *and* J. E. PETAVEL, *F.R.S.*

In Part I. the change of temperature with height was considered. The rate of fall, or temperature gradient, is measured in degrees centigrade per 100 metres. The average gradient for the present year was given for the various English stations at each successive 500 metres above sea-level. The values for Glossop Moor are 1·24° C., 0·91° C., 0·61° C., and 0·33° C. per 100 metres at heights of 400, 750, 1250, and 1750 metres. These results were compared with the observations made in previous years in America at Blue Hill, and in Europe at Berlin, Oxshott, and Crinan.

The temperature gradient varies: (1) with the wind direction, and is at all levels a maximum for a N.W. wind; (2) with the amount of clouds, and is at all levels a maximum on clear and fine days; (3) with the wind velocity, and is a maximum for low velocities.

Diagrams illustrating these facts were shown.

Part II. dealt with the question of wind velocity. The average velocity had been calculated for all stations at ground level, 500, 1000, and 1500 metres. For Glossop Moor the averages are 13, 26, 30, and 33 miles per hour respectively at these heights. Except at the ground level, where it is influenced by local conditions, the average wind velocity at each height differs but little from station to station.

Comparing the velocities at various heights it is found that above a height of 500 metres the average increase is 0·7 mile per hour per 100 metres difference of level.

Curves showing the connection between the wind velocity and barometric gradient were exhibited.

The effects of the absolute barometric height, of the season of the year, and of the wind direction were also considered.

With regard to the alteration of wind direction with height, the results indicate the usual slight rotation in a clockwise direction, *i.e.*, a west wind tends to become more northerly, &c.

A number of subsidiary questions, such as the conditions prevailing during temperature inversions and the occurrence of vertical air-currents were discussed.

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8. *Sixth Report on the Investigation of the Upper Atmosphere by means of Kites.* See Reports, p. 99.

9. *On the recent Balloon Ascents.*
By W. A. Harwood *and* J. E. Petavel, *F.R.S.*

In connection with this investigation balloons carrying the new meteorograph devised by W. H. Dines, F.R.S., were sent up daily between July 22 and 27, 1907, from five British stations, under the direction of the Meteorological Office and of the Joint Committee of the Royal Meteorological Society and the British Association. Out of the total number, twelve instruments have been recovered. The heights attained ranged up to about twenty kilometres.

A brief account referring specially to the Manchester Station was given, and a diagram showing the variation of temperature with height as derived from two of the most successful records was exhibited.

The curves showed an average temperature gradient of about 0·8 cent. per 100 metres up to a height of nearly eight kilometres, and a substantially constant temperature above this level. The lowest temperature is in most cases 40° or 45° C. below zero.

10. *Report on Meteorological Observations on Ben Nevis.*
See Reports, p. 100.

11. *Results of recent Researches on the Physics of the Earth.*
By Dr. T. J. J. See.

12. *Report on the Magnetic Observations at Falmouth Observatory.*
See Reports, p. 93.

Section B.—CHEMISTRY.

President of the Section—Professor Arthur Smithells, B.Sc., F.R.S.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

The year which has elapsed since the meeting of our Section at York has been eventful in the most melancholy of ways; the losses sustained by our science have been unparalleled. The passing bell seems to have tolled almost without intermission as one after another of our masters has been taken from us: in Russia, Mendeléef, Menschutkin, and Beilstein; in France, Berthelot and Moissan; in Holland, Bakhuis-Roozeboom. Whilst in some of these cases we may find consolation in contemplating a length of life and sustained activity beyond what we might have dared to expect, in others our regret is increased by the sense of untimeliness and of vanished hopes. I am tempted to speak of the work of such mighty men as Berthelot and Mendeléef, to dwell upon the discoveries by which they transformed the whole fabric of chemical science; but this is not the occasion on which to offer an estimate of the labours of those who have passed away. I can only say that in the bond of brotherhood which the pursuit of science establishes among the different nations of the earth we who are Englishmen feel and deplore these losses as our own.

I must not omit to allude also, as I do with deep regret, to the death in our own country of two such ardent and fruitful workers as Cornelius O'Sullivan and Robert Warington.

These words were already in print when again we were called to mourn the loss of one of our greatest men, one who but a year ago was the subject of our special rejoicings, and whose vigour of body and youthfulness of spirit seemed to promise the long continuance of a noble and an extraordinarily fruitful life. We can at least feel thankful that William Henry Perkin lived long enough to learn in what honour and esteem his name was held, not only among his countrymen, but by all the chemists of the world, and by the leaders of those great industries of which he was justly acclaimed the founder. For more than a generation Sir William Perkin had been one of the most familiar figures at the meetings of this Section, and greatly shall we miss his gentle presence, his wise counsel, and his valued contributions.

I can, perhaps, best occupy your time to-day by attempting to give some account of the present state of the scientific subject to which I have paid most attention. The topic of flame, after a long period of repose, has aroused much interest during late years, and I think we may say that some considerable progress has been made in its elucidation, although in this, as in all other subjects of scientific inquiry, the more closely we scrutinise it the more impressed must we be with what still remains unknown.

One of the first questions that meet us in the study of flame is that of the temperature at which in any given case the phenomenon becomes evident. Here,

I think, a great clarification of view has taken place. The old idea that there existed a fixed temperature at which inflammation suddenly took place cannot now be maintained, and the term 'ignition temperature' has acquired a different meaning. It is now known that in a very great number of cases a mixture of two flame-forming gases, when gradually raised in temperature, will develop luminosity quite gradually, *pari passu*, with the chemical combination that is being induced. This phenomenon is, of course, known universally in connection with phosphorus, but it is not so widely known in connection with other combustible substances. There are some simple facts that seem as if they never could gain admission to text-books, and I do not think I have known more than a single chemical book that is not likely to leave a student under the impression that the phosphorescence of phosphorus is an almost unique phenomenon. I do not know how many times the independent discovery has been made that sulphur, arsenic, carbon disulphide, alcohol, ether, paraffin, and a whole host of other compounds, inorganic and organic, will phosphoresce as truly as phosphorus itself; that, in fact, phosphorescent combustion is the normal phenomenon antecedent to what we ordinarily call flame.

This is, after all, only in harmony with the general truth that chemical combination between two gases does not set in suddenly, but comes into evidence quite gradually as the temperature is raised from a point at which the action, if it occurs at all, is so slow as to be negligible. The increase in the rate of combination is, of course, very rapid as compared with the increase of temperature, a difference of about 10° C. serving to double it. The interval between the beginning of phosphorescence and the production of vigorous flames may therefore be very short. In the case of phosphorus this interval, being from 7° to to 60° C., includes ordinary atmospheric temperatures; hence the phosphorescence of phosphorus is a phenomenon that could not well be overlooked. If the prevailing terrestrial temperature were below 7° C., at which, under normal air-pressure, the phosphorescence of phosphorus ceases, it is possible that this element might never have acquired its peculiar reputation; it would not have shone in the dark, and in lighting it with a taper the phosphorescent interval would have been passed over as quickly as is ordinarily the case in the ignition of sulphur, paraffin, and other common combustibles. To make phosphorescence apparent in these last cases it is necessary to take special care to heat up a mixture of the combustible gas and air gently, and to maintain it at a temperature approaching, but not quite reaching, that of ignition. There is no simpler way than that used by Sir William Perkin, who brought the combustible substance near to, or in contact with, a massive metal ball previously heated to the suitable temperature.

The change from phosphorescence to ordinary flame is not sudden, but the appearance of ordinary flame is the end point of a continuous, though rapid, development. This end point is the temperature of ignition. What, then, determines the temperature of ignition? The answer to this question has been given with characteristic conciseness by Van't Hoff as 'the temperature at which the initial loss of heat due to conduction, &c., is equal to the heat evolved in the same time by the chemical reaction.'

We may obtain a clear idea of the meaning of temperature of ignition by supposing a combustible mixture of gases such as that of air and the vapour of carbon disulphide to issue through an orifice into an indifferent atmosphere. If we surround the orifice by a ring of platinum wire, which is gradually heated up by a current of electricity, a flame will gradually make its appearance. If, as soon as this is observed, the heating of the wire by the current be discontinued, the flame will disappear; it is, in fact, not self-supporting, but depends on the accessory supply of heat through the electrically heated wire. If now we raise the ring to a higher temperature we shall get a brighter flame, owing to an increased rate of chemical action, and at last we shall reach a point where it is possible to cut off the electric current without causing at the same time the extinction of the flame. This is the true temperature of ignition, the temperature at which the reaction proceeds at a rate just sufficient to overbalance the loss of

heat by radiation, conduction, and convection from the burning layer of gases, so that the next layer is put in the same state, and steady combustion proceeds.

Phosphorescence has been spoken of as degraded combustion, and, though literally the appellation is correct, I think it is liable to be misunderstood. Again, it is often supposed that phosphorescence is necessarily associated with the formation of incompletely oxidised products. This may be the case in a chemical system which is capable of affording different products at different temperatures, but it is not an essential feature; the phosphorescent combustion of sulphur, for example, affords nothing but sulphur dioxide.

Temperature of ignition is, then, neither a temperature at which combination suddenly begins nor one dependent solely on the nature of the combining gases. It will vary with the proportion in which the gases are mixed and with their pressure and other circumstances. Notwithstanding the simplicity of this conception, it must be admitted that there are many obscure facts connected with the ignition of gases. The inflammability of gaseous mixtures is not necessarily greatest when they are mixed in the proportions theoretically required for complete combination; the influence of foreign gases does not appear to follow any simple law; the presence of a very small quantity of a foreign gas may exercise a profound influence on the ignition temperature as in the case of the addition of ethylene to hydrogen. When a mixture of methane and air is raised to its ignition temperature, a sensible interval (about 10 seconds) elapses before inflammation occurs. These facts are cognate to others which have increased upon us so abundantly in connection with the influence of moisture on chemical change. The study of the oxidation of phosphorus in particular brings us among rocks and shoals. Apart from the influence of moisture on the combination we have the limitation of the process by a certain tension of oxygen and by minute quantities of a vast number of chemical substances, among which, in spite of much labour, no other common bond can be found. We do not know what oxide is initially formed in the oxidation, and the existence of the oxides P_4O and P_2O is as confidently disputed as it is affirmed. There is some reason for believing that the phosphorescence connected with phosphorus succeeds the formation of one oxide and accompanies the formation of another. The state of the oxygen, whether atomic, ionic, or molecular, which acts on phosphorus, the induced oxidation of other substances, the ionisation of air accompanying the oxidation—these are all matters concerning which there exists a bewildering literature that hangs over us like a cloud. The whole of my Address would, in fact, not suffice for a summary of the state of our ignorance about the oxidation of phosphorus. The subject, simple as it appears at first sight, is really involved with a vast number of unsolved chemical problems the elucidation of which would throw much light on chemical action in general. I may, perhaps, bequeath the topic to some successor in this Chair as one which may serve to illustrate the advance of knowledge since these present days of darkness.

The structure of flames has always been regarded as dependent upon the chemical changes taking place in the differentiated regions, but until recent times little attention has been given to any question beyond the cause of the bright luminosity of hydrocarbon flames. In a flame such as that of hydrogen or carbon monoxide, where we have some reason to suppose that the same kind of chemical transaction is taking place throughout the region of combustion we should not expect to find a differentiation of structure, and, as a matter of fact, we do not find any. Erroneous ideas have gained currency from the use of impure gases, and hydrogen is still described as burning with a pale blue flame, although Stas long ago stated that if the gas is highly purified, and the air freed from dust, the flame even in a dark-room can only be discovered by feeling for it; a fact consistent with the line spectrum of water lying wholly in the ultra-violet. The presence of a very small quantity of free oxygen in carbon monoxide destroys the perfect simplicity of the single shell of blue flame with which the purified gas burns, and in other flames small quantities of gaseous impurities or of atmospheric dust give rise to features of structure and halos which have been frequently supposed to pertain to the flame of the combining gases. The fringe of a flame in air may be often tinged by the presence of oxides of nitrogen.

No flame better illustrates the relation of structure to chemical processes than that of cyanogen, where the two steps in the oxidation of the carbon are clearly marked out in colour. Apart from hydrocarbon flames, very few others have been carefully explored from this point of view. There is, unfortunately, no gas composed of two combustible gaseous elements; and, though such gases as the hydrides of phosphorus and sulphur do not fall far short of this, the experimental difficulties of an exact exploration of their flames are very great. We are thus prevented from studying the flame of a composite combustible in its simplest form.

The flames of hydrocarbons have naturally been the subject of most frequent investigation. The use of single hydrocarbons instead of the mixtures present in coal-gas and other common combustibles has simplified the study considerably. Two problems stand out prominently: one is to trace the steps in the oxidation of the hydrocarbon, the other to account for the bright patch of yellow luminosity. With regard to the question of the luminosity, I do not think there is any longer doubt about its being due essentially to the separation within the flame of minute solid particles of what is practically carbon. The separation seems to be adequately explained by the high temperature of the blue burning walls of the flame, which decomposes the unburned hydrocarbon within. In a similar way arsenic and sulphur and phosphorus are liberated within flames of their hydrides; but these elements, being volatile, do not appear as solids unless a cold object be placed within the flame. In the case of the hydride of silicon the liberated element at once oxidises to form the solid non-volatile oxide, which gives a bright glow.

The mode in which a hydrocarbon yields carbon by the application of a high temperature has been the subject of experiment and of hypothesis; but neither the view of Berthelot, that the carbon results from a continuous coalescence of hydrocarbon molecules with elimination of hydrogen, nor that of Lewes, according to which the formation and sudden decomposition of acetylene is the essence of the phenomenon, appears to me to be in harmony with the experimental facts; and I am not aware that either view has secured any support from other workers in this field. It is certainly not easy to ascertain experimentally the changes undergone by a single hydrocarbon as its temperature is raised, and at the last it may be objected that the course of events in contact with the solid walls of a containing vessel is not necessarily the same as that within the gaseous envelope of a flame. I am glad to think that there is promise of further light on this subject from the work of Professor Bone.

The course of oxidation of hydrocarbons has been the subject of very careful and fruitful study. The old view that a selective or preferential oxidation of the hydrogen always took place, that with a restricted supply of oxygen the hydrogen was oxidised and the carbon set free, is, I think, no longer maintained by anyone who has studied the question. The explosion of ethylene with its own volume of oxygen, which leaves us with practically all the carbon oxidised and all the hydrogen free, is fatal to this view. Again, when hydrocarbons are burned in a flame with a restricted supply of air, as is the case in the inner cone of the flame of a well-aërated Bunsen burner, there is clearly no separation of solid carbon, and the products of combustion when withdrawn and analysed disclose the presence of much free hydrogen and no unoxidised carbon. In describing this experimental fact I have spoken of it as the preferential oxidation of carbon. I have always thought it pedantic to quarrel with that expression; for, in speaking of a chemical transaction, we usually include only a description of the initial and final states of combination. I should be sorry, however, to detach the expression from the facts it describes and to exalt it into a general doctrine. That would be quite inadmissible, and, if there is any danger of misunderstanding, it would be better to avoid using the expression.

The admirable researches carried out in the University of Manchester by Professor Bone and his collaborators have afforded most valuable information as to the oxidation of hydrocarbons at temperatures extending from those of incipient oxidation up to the highest ones that prevail in a flame. According to Professor Bone, the oxidation of a hydrocarbon involves nothing in the nature of

a selective or preferential oxidation of the carbon or the hydrogen; but it occurs in several well-defined stages, during which oxygen enters into and is incorporated with the hydrocarbon molecule, forming oxygenated intermediate products, among which are alcohols and aldehydes. The reaction, just referred to, between ethylene and an equal volume of oxygen is, according to Professor Bone, to be represented by the scheme:

$$\begin{array}{ccccccccc} CH_2 & & CH.OH & & CH.OH & & H_2C:O & & H_2+CO \\ \vdots & \rightarrow & \vdots & \rightarrow & \vdots & \rightarrow & & \rightarrow & \\ CH_2 & & CH_2 & & CH.OH & & H_2C:O & & H_2+CO \end{array} .$$

There can be no question about the facts on which this scheme is based, and they are a new and important addition to knowledge.

It is a great aid to the study of chemical changes, when we can resolve them into stages, whether or not these stages be realisable under certain experimental conditions In this way we can get a clear view of the relationship between the action under one set of circumstances to the action under another set; and in this way also we can often establish rational links between reactions which at first sight seem quite disconnected. Intermediate reactions are much used to elucidate cases of contact action, and in the processes of organic chemistry they are almost universally assumed.

I am far from wishing to disparage these practices, but I think it important that we should realise how far we are dealing with convenient devices and how far with ascertained facts. The isolation of an intermediate product under one set of circumstances is in itself no proof that this product is transitorily formed when the reaction is proceeding under another set of circumstances; and if we were to assume generally that because we can represent a chemical transaction as if it were due to a successive construction and destruction of a series of molecular edifices it actually does take such a course, we should, I think, be making the same kind of mistake as to suppose that in the application of two differently directed forces to a body at rest, the body will move successively in the direction of each force instead of moving immediately in the direction of their resultant. I know that I may be considered hypercritical, and perhaps obstinate, in this matter; but I wished to state the reasons that prevent me from accepting entirely the interpretation which Professor Bone has given to his experimental results, and to draw attention to a question of general importance that has not, I think, received the attention it deserves.

The mode of burning of carbon, whether in the free state or as a constituent of a compound, is not at all easy to determine; and notwithstanding many investigations, among which must be specially mentioned those of Professor H. B. Dixon and his collaborators, so simple-looking a question as whether carbon forms carbon monoxide by directly uniting with oxygen, or only by reducing carbon dioxide, is still a matter of uncertainty.

Our knowledge concerning the question of flame temperatures has been much improved in recent times, thanks mainly to the admirable work of M. Le Chatelier. The well-known memoir of Mallard and Le Chatelier on the explosion of gases supplied the data which first permitted of a moderately exact calculation of flame temperatures, and the perfection of the thermo-couple by M. Le Chatelier gave us the first instrument that could be used directly for making a satisfactory measurement. The uncertainty connected with this subject may be well illustrated by quoting the temperatures that have at different times been ascribed to the flame of coal-gas when burnt in a Bunsen burner, where we have had values varying from 1230° to 2350° C.

The question of calculating the temperature attained during combustion by reference to calorimetric values, specific heat, dissociation, and other considerations is to form the subject of a joint discussion with Section G during the present meeting, so that I shall not here enlarge upon it.

With regard to the use of thermo-couples, I may remark that the practical difficulties have been successfully met. The chief difficulty is, of course, to secure that the thermo-junction attains as nearly as possible the temperature of the

region in which it is immersed. As ordinary flames consist of thin shells of burning gases, on either side of which there is a very rapid fall of temperature, it is necessary to use thin wires, and to dispose them so that there is no appreciable drain of heat from the junction. By using wires of different gauge for the couples it is possible by extrapolation to arrive at a temperature for a couple of infinitely small cross-section, and it is also possible to make a correction for the superior radiating power of the couple as compared with the flame-gases. Without this last correction a maximum temperatnre of 1770° was obtained for the Bunsen flame by Waggener in Germany, and 1780° by White and Traver in America. Correcting for radiation, Berkenbusch found 1830° as the maximum temperature.

M. Féry, by an ingenious application of his beautiful optical pyrometer to a flame containing sodium, gives 1871° as the highest têmperature of the flame of a Bunsen burner burning coal-gas.

The consideration of flame-temperatures has become of increasing importance in the arts owing to the use of the Welsbach mantle as a means of deriving light from coal-gas. The great improvements which have been made in the efficiency of atmospheric burners depend primarily on the fact that the smaller the external surface we can give to a flame consuming gas at a fixed rate the higher must be the average temperature; and since the emission of light from a mantle is proportional to a high power of the absolute temperature, a small increase of temperature is of great effect on luminosity.

The acetylene-oxygen flame in which a temperature of about 3500° prevails, not very different from that of the electric arc, is the hottest of the hydrocarbon flames, and finds some important practical uses.

I have already said something about the luminosity of flames so far as relates to the separation and glow of solid carbon. But there remains the more general question of the luminosity of flames containing nothing but gases. The older explanation of the emission of light from combining gases said no more than that the energy liberated during the reaction and appearing as heat raised the product to incandescence—that is to say, so increased the velocity of its molecules and the violence of their collisions that vibrations were set up whose wave-lengths lay within the limits of visible radiation. This explanation has long been questioned, and there is now, I think, a very general agreement that it will not suffice. The average temperature, in fact, prevailing in a flame, if attained in the product of combustion by the supply of heat from outside, does not suffice to make that substance luminous. We are therefore thrown back upon the conclusion that the generation of light in a flame is not a consequence, though it is an accompaniment, of the elevation of temperature. The question now is, Can we go any further? To do this we are led to consider individual molecular transactions instead of statistical averages, and the view presents itself that the combining atoms may, in losing their chemical energy, form directly systems of independent vibration where the radiation is such as to fall within the limits of visibility. If we picture such vibrating systems momentarily formed, it is easy to see that by their collision one with another they may acquire in a secondary way increased translational motion, and so lead to a state of things where the greater part of their energy is degraded in the form of heat. The high temperature of a flame would then be a consequence rather than a cause of its light.

This subject of the mechanism of luminosity, however, like so many others, has now become involved with the theory of electrons, and a chemist may be excused if he hesitates to pursue the subject further. Some years ago I called attention to the scantiness of our knowledge of the chemical changes that take place when metallic salts are used in flames for the production of spectra. Though there was general agreement that, for example, the yellow flame produced by common salt was due to the liberation and glow of metallic sodium, there was no agreement as to how the sodium was set free.

Arrhenius, pursuing the analogy which exists between the laws governing matter in the gaseous state and in the state of dilute solution, had previously been led to the view that the electrical conductivity of flames containing salt-vapours was due to ionisation of the salt throughout the volume of the flame. It appeared

possible therefore that the luminosity might be ascribed likewise to the metal separated in the ionic state. Experimental investigation undertaken with a view to elicit information on this subject seemed to favour the view that the metal was reduced by chemical processes, and that it glowed in the un-ionised condition. Evidence seemed to point to the conclusion that, for example, when common salt is introduced into the flame of coal-gas the sodium chloride yields sodium by the conjoint action of steam and reducing gases; when liberation of the metal was prevented by adding a large quantity of hydrochloric acid to the flame the glow disappeared, but the conductivity was not always diminished. The fact that sodium salts, including the chloride, impart their characteristic glow to the flame of cyanogen and to other flames in which water is absent leads to some difficulty in finding a chemical explanation, and it must be admitted that a direct thermal dissociation of an alkaline halide or oxide is not out of the question. The interval of detachment of the metallic atom may be exceedingly brief, but it must be remembered that even so short a time as the interval between the molecular encounters in a gas at a high temperature is still sufficient for the emission of thousands of undisturbed characteristic vibrations. The experiments to which I have alluded have been followed up with great industry and success by Professor H. A. Wilson, who has added much to our knowledge of the electrical condition of the flames containing vaporised salts; but the question of the condition of the luminous gas is still far from being settled. Very interesting and important investigations have been carried out by Lenard, who has shown that the stream of luminous vapour produced from a sodium salt in a Bunsen flame is deflected in an electric field in such a way as to indicate that the vapour is positively charged; but he gives reason for believing that the charged condition is intermittent with the neutral condition. The lines in the spectrum of an alkali metal are divisible, as is well known, into distinct groups or series, in each of which the oscillation frequencies corresponding with the lines are in a definite mathematical relationship. The principal series, which include the lines seen individually as such in ordinary flame spectra, are, according to Lenard, due to the electrically neutral atoms. In a salted spirit flame, and in other flames of low temperature where only lines of the principal series are represented, the stream of luminous gas does not behave in an electric field as if it were charged. In the flame of coal-gas burnt in a Bunsen burner the salt-vapour gives, in addition to the distinct lines of the principal series, diffuse bands of luminosity on the dark background, which, according to Lenard, represent the undeveloped subordinate series; and it is the atoms emitting these series that are deflected in the electric field. It is inferred, therefore, that the light in a salted Bunsen flame comes from different groups of centres of emission—the principal series from the neutral atom, and the lines of the first, second, and third subordinate series from atoms which have lost respectively one, two, and three electrons. Lenard goes further, and shows that the salt-vapour in a Bunsen flame, as in the flame of the electric arc, emits these different kinds of radiation from different structural regions; thus the vapour at the edge of the flame is electrically neutral and gives only the lines of a principal series.

The negative electricity in a salted flame would, according to Lenard, be disembodied, and recent experiments by Gold confirm the view that the negative carrier in flames is a free electron. In connection with this subject I ought to allude to an investigation by Tufts, which seems to throw some doubt on the conclusions which were drawn from the experiments made by Professor Wilson, Dr. Dawson, and myself; and I must also mention an important contribution to the subject recently made by Professor Hartley, in which considerable light is thrown upon the chemical changes undergone by compounds of the alkaline earth metals when they are introduced into flames, and upon the relation of these changes to the various spectral features. I am afraid, however, that it would be wearisome if I were to prolong this summary, and I must be content to leave it without doing justice to those who are engaged upon the work. The subject is obviously one of fundamental importance in relation to spectrum analysis, and my own slight connection with it has only strengthened my opinion that there is still a great deal connected with the genesis of spectra that requires the attention of the chemist even more

than that of the physicist. Spectrum analysis arose under the joint influence of Bunsen and Kirchhoff, and I think its problems still call for more combined work on the part of chemist and physicist than has latterly been the custom.

Having given a short summary of the present state of knowledge on one particular chemical topic, I may perhaps be permitted to conclude my Address with a few general observations relating to the science as a whole.

The contemplation of such a life as that of Berthelot makes us realise in a vivid way the progress of chemical science. He was a chemist without limitation, his activity extending over the whole range of the science, physical, inorganic, and organic. Whilst we must not forget his exceptional powers, we cannot help feeling how different in its extent was our science when he entered upon his labours from what it was when they ceased, and we cannot help feeling how vain it now is for anyone to hope for so imperial a sway.

Yet it is difficult to believe that the state of chemistry can ever have been more interesting than it is at the present moment, or that anyone who sighs for the good old times can do so from anything but the love of a quieter life. We need not go back more than twenty years to find a sharp contrast. At that time there was indeed no want of activity, but it was that of a band of travellers who had left their frontier adventures far behind, and were marching steadily over a wide and almost uninterrupted plain. To-day we are among the mountains, with new peaks and prospects appearing on every side. Truly a steady head is required; and well may we ask, Whither are we going and where is the path of progress and of safety? I rejoice to live in such times; but I feel no competence to describe them, still less can I pretend to have vision keen and comprehensive enough to let me figure as a guide.

One of the penalties of devotion to a progressive science is the constant feeling of being left behind, and the knowledge that, while we are attending to our personal task, things are happening, near or far, that may, for all we know, be affecting the simplest facts and the most elementary principles on which we have been accustomed to rely. This is a feeling that may well prevail at the present day. At the same time I do not think there is any occasion for panic, and I cannot help regretting the somewhat sensational language that has been used, even within our own circles, in regard to recent discoveries. The revelations attendant upon the investigation of radio-activity do indeed mark a distinct epoch in the history of chemical discovery, but that they entail anything like an unsettlement of our scientific articles of faith is not to be admitted for a moment. They make us realise in perhaps a not unprofitable way that scientific knowledge and scientific theories are necessarily proximate, never ultimate, and that ideas which may have been entertained for a long time without modification, and so have begun to seem perpetual, are, after all, only provisional.

There is certainly some embarrassment on finding that a substance like radium, which according to the conventions would be called a chemical element, breaks up so as to give substances which, according to the same conventions, are likewise called elements. But the confusion is one of terminology and not of ideas. I think it likely that few chemists of my own generation have been in the habit of regarding the conventional elements as the ultimate compositional units of matter. We know that in our own country distinguished men of science like Sir William Crookes and Sir Norman Lockyer have always insisted on the complex nature of the elements, and I suspect there are many among us who might own to having made sober, if unsuccessful, attempts at the resolution of elements before the days of radium.

The perplexities of chemists at the present day do not come, I think, from the novelty of the ideas that are being presented to them, but from the great rapidity with which the whole science is growing, from the invasion of chemistry by mathematics and, in particular, from the sudden appearance of the subject of radio-activity with its new methods, new instruments, and especially with its accompaniment of speculative philosophy. There is an uneasy feeling that

developments of great importance to the chemist are being made by experiments on quantities of matter of almost inconceivable minuteness. Spectrum analysis of course took chemistry beyond the limits of the balance, but the new materials which it disclosed could at least be accumulated in palpable quantity. With radio-activity we seem, in relation to the ponderable, almost to be creating a chemistry of phantoms, and this reduction in the amount of experimental materials, associated as it is with an exuberance of mathematical speculation of the most bewildering kind concerning the nature, or perhaps I should say the want of nature, of matter, is calculated to perturb a stolid and earthy philosopher whose business has been hitherto confined to comparatively gross quantities of materials and to a restricted number of crude mechanical ideas. He is tempted to think of Falstaff's reckoning and to exclaim with Prince Henry, 'Oh, monstrous! but one halfpennyworth of bread to this intolerable deal of sack!' Experimental science has latterly been spun to greater and greater fineness, until in the region of the N rays the objective element seems to have disappeared altogether.

I should, however, gravely abuse the position in which I am allowed to speak for the moment as a representative of chemists if I failed to express profound admiration for the masterly work which has been accomplished by the pioneers of the science of radio-activity. All that I wish to say beyond that, is in explanation of a certain awe or trepidation which chemists of the older school may feel in the presence of such bold explorers; and I am the more tempted to say something on the subject, because in recent times, before the advent of radium, a good deal has happened which has given chemists occasion to ask themselves whether chemistry was not beginning, as it were, to drift away from them.

The most conspicuous development of the science during the past twenty years has been, of course, on the physical side, and abundant have been its fruits; but it has seemed to demand from chemists habits and endowments which they did not normally possess, and which they could not easily acquire. I was much struck by a remark made to me a few years ago by a distinguished chemist, who is, I think, the most perfect manipulator I have ever seen at work, to the effect that he felt himself submerged and perishing in the great tide of physical chemistry which was rolling up into our laboratories. Now, it is precisely such men that must be preserved to chemistry. Though chemistry and physics meet and blend, there is, I believe, an essential difference between the genius of the chemist and the genius of the physicist, and I venture to think that some insistence on the primary functions of a chemist is not untimely. The chemist's first qualification is that he shall be master of a peculiar craft; his greatest merit that he is a consummate workman; his distinctive power a nicety of discrimination in questions affecting the composition and quantity of materials. He is not given to elaborate theories and is usually averse to speculation; nor has he usually an aptitude for mathematics. Such the normal chemist is, or was, and such I hope he always may be—naked perhaps in some respects, but unashamed.

There seems to be a solicitude in some quarters to make a chemist something more than a chemist, a solicitude which, if gratified, will, I believe, make him something less than one. We are told, for example, that a chemist should be a mathematician. I do not admit it for a moment. Some mathematics he must of necessity have—that has always been admitted—but in proportion as chemistry develops on the mathematical side does it become important, not that our chemists should be trained in mathematics, but that they should be more than ever carefully trained in the art of exact experiment; that their methods of work, their powers of observation, and, if possible, their experimental conscience, if I may use the expression, should acquire a finer edge. There is never more cause for anxiety than when we see a mathematical theory awaiting the delivery of the confirmatory facts, and there is nothing more important for chemistry than the continual recruiting of that old guard which will be ever ready to stand to arms on the appearance of an eager theorist.

I do not for a moment wish to disparage the adventurous spirits within or outside our science, still less do I wish to range myself with those who meet new ideas with mere objurgation or raillery. We must be content to see new

alliances and new activities on the frontiers that separate us from other sciences; content to see many new kinds of chemistry arise in which we cannot all effectually participate. Chemistry is becoming bewildering in its extent, and it would be a great misfortune if this led to the notion that every chemist must try to enlarge his ambit to its confines and fit himself for every variety of work. Those of us who have responsibilities as teachers cannot, I think, be too careful, lest in the attempt to secure breadth we may encourage shallowness and fail to give our students that peculiar and time-honoured discipline in exactitude of work in chemistry proper, which has characterised the chemists of the past, and which is infinitely more important than superficial dealings with a great variety of processes and appliances. I confess that I have frequent misgivings as to whether our modern courses of instruction may not tend to turn out chemists more learned in the science and less perfect in the art than was the case under the ancient *régime*. There was, after all, great virtue in the system which often detained a student day after day, or perhaps week after week, on a single problem of chemical composition such as is involved in the exact analysis of fahl-ore. It is not easy to meet all requirements, but I think we shall all agree that, whatever is left undone, we must make a chemist a good craftsman. It is of the utmost importance that those whom we send out to work in the newer fields shall take with them the resources that have proved most serviceable in the old, and I think it is by supplying such men for special service, rather than by attempting to shift the centre of gravity of the whole system of chemical education, that we can best serve the newer interests.

Another perturbation within the chemical camp in recent times has come from the region of philosophy. Even before the days of radium we have been accused of clinging too fondly to our atomic theory and of stating our knowledge too exclusively in terms of that theory. We are said to have drifted into a dogmatism as real as any we ourselves have had to attack, and to shut our eyes to the light which will enable us to orient ourselves truly in the wide realm of thought. The answer that most of us would give would be, that we value our hypotheses according to their productiveness in new knowledge, and that it is, on the whole, perhaps better to over-exalt an hypothesis that is fertile than from high considerations of philosophy to allow our ideas to become so fluid that they can afford no rigid framework for thought. I think that the attempts to view chemical phenomena apart from the atomic hypothesis, interesting as they undoubtedly are, have not made us feel that this hypothesis has either misled us in any matter of fact or obscured any pathway that we might have followed with greater profit. The value of the thermo-dynamical treatment of chemical problems is attested by its fruitfulness in promoting fresh discoveries; and here we may welcome a valuable adjunct to the atomic hypothesis. But I do not think we are called upon to acclaim a new method of treating old questions unless it promises some more tangible result than an alleged improvement of our intellectual morals.

If, as I have ventured to hint, mathematics brings with it an element of danger into chemistry, I think that the intrusion of metaphysics would give far greater cause for apprehension. Philosophy always stands with open arms desiring a closer embrace of all the sciences, of which she declares herself to be the fond mother, whilst Science, as we understand the term, has stood reluctant, suggesting, as someone has wittily remarked, that she regards Philosophy rather as a mother-in-law. It may perhaps be desirable, especially in the present state of things, that scientific men should allow themselves to become a little more interested in deep questions affecting all knowledge, and should at least examine with some care the gifts that Philosophy is so anxious to bestow upon us. I have a fear that otherwise in the elaboration of scientific theory we may find ourselves embroiled in an unequal contest with what I cannot but regard as the traditional enemy—I mean the unmitigated metaphysician—and the suggestion that I make is, to tell the truth, not so much from the hope of gain as from the desire for self-defence and the safe preservation of the methods that have served us so well in the past.

I think the accusation that we delude ourselves into the belief that our hypotheses are final truth is not true of any thoughtful chemist; the great men of

science have surely possessed that quality of mind which philosophy would most approve. If, as has often been remarked, Faraday was mathematically-minded, though untrained in mathematics, it seems not less true that he stood in the same relation to philosophy. When, for example, he was asked to express his opinions on the atomic theory, he wrote as follows:—

'I do not know that I am unorthodox as respects the atomic hypothesis. I believe in matter and its atoms as freely as most people—at least I think so. As to the little solid particles, which are by some supposed to exist independent of the forces of matter, and which in different substances are imagined to have different amounts of these forces associated with, or conferred upon, them (and which even in the same substance, when in the solid, liquid, and gaseous state, are supposed to have like different proportions of these powers), as I cannot form any idea of them apart from the forces, so I neither admit nor deny them. They do not afford me the least help in my endeavour to form an idea of a particle of matter. On the contrary, they greatly embarrass me; for after taking account of all the properties of matter, and allowing in my consideration for them, then these nuclei remain on the mind, and I cannot tell what to do with them. The notion of a solid nucleus without properties is a natural figure or stepping-stone to the mind at its first entrance on the consideration of natural phenomena; but when it has become instructed, the like notion of a solid nucleus, apart from the repulsion, which gives our only notion of solidity, or the gravity, which gives our notion of weight, is to me too difficult for comprehension; and so the notion becomes to me hypothetical, and, what is more, a very clumsy hypothesis. At that point, then, I reserve my mind as I feel bound to do in hundreds of other cases in natural knowledge.'

This is the attitude of mind, I think, of all thoughtful chemists; if they do not exhibit it ostentatiously it is only because it is as disturbing to the proper work of a chemist for him to be constantly dwelling on the inward nature of his hypotheses as it is distracting in ordinary life to have men always talking about their emotions.

Few, I think, will deny that the atomic theory stands to-day as an indispensable instrument for productive chemical work; it has neither had its day nor ceased to be. Physicists have never been quite satisfied with the hard, indivisible ball of specific substance and definite mass which has served chemistry so well. They have given it bells, have made a vortex ring of it, and have indeed done much that few chemists can understand to make it meet the exacting requirements of their science. But to us it has always been the same; what we have done to it has been external; we have given it, vaguely perhaps, a charge of electricity, a store of energy; we have attached the hooks or rods of valency, but we have not meddled with its interior. We are now called upon by chemical considerations of change of composition, as well as by other considerations more recondite, to subdivide our atom, to credit it with an unsuspected store of energy, to consider it a congeries of unsubstantial electrons. We should wish, of course, to know that the evidence is good enough, but otherwise there can be no possible objection from our side; it will undo nothing that has been done, and we may have good hopes that it will lead to the doing of many new things in chemistry. The newer theories are in consonance with the old in one most vital point: they afford those mental pictures of phenomena which most of us find indispensable for fruitful work. They do not belong to what Professor Schuster has characterised as 'the evasive school of philosophy.' 'Those,' he says, 'who believe in the possibility of a mechanical conception of the universe, and are not willing to abandon the methods which from the time of Galileo and Newton have uniformly and exclusively led to success, must look with the gravest concern on a growing school of scientific thought which rests content with equations correctly representing numerical relationships between different phenomena, even though no precise meaning can be attached to the symbols used.' Most of us, I think, will take comfort in this pronouncement and rejoice that if our conception of the atom is to be transformed, it may still be represented as having some kinship with what Sir Henry Roscoe's famous examinee described as the 'square blocks of wood invented by Dr. Dalton.'

Discussion on Valency.

(i) *The Nature of Valency.* *By* Professor W. J. Pope, *F.R.S.*

(ii) *Zur Valenzfrage.* *By* Professor A. Werner.

(iii) *Valency.* *By* Professor R. Abegg.

The polarity of valency is distributed through the periodic system according to a well-defined law; the valency is strongest on the left, and least on the right side, increasing with the atomic weight in the principal groups, decreasing in the sub-groups on the left side of the system, while on the right-hand side they both increase in the same order as the atomic weights. Decreasing + polarity and increasing − polarity are consequently identical.

The *valency number* is very simple and constant in compounds with atoms of different polarity (*heteropolar* compounds), while most variable in compounds of nearly equal polarities (*homeopolar* compounds). All elements are able to act amphoterically, being positive against stronger negative atoms, and negative against stronger positive ones, as is proved either by electrolysis or hydrolysis of their compounds.

The maximum valency number is limited for both + and − valency, the former being the number of the group, the latter the number which makes this 8. The strength of valency affinity decreases with increasing number of valencies; thus the polarity with the smaller number of valencies becomes prominent and forms the 'normal valency,' while the other forms the 'contravalency,' thereby giving rise to the following table:—

Number of Group of Period. System	I.	II.	III.	IV.	V.	VI.	VII.	VIII. = 0
Normal valency . . .	+1	+2	+3	±4	−3	−2	−1	−0+0
Contravalency . . .	−7	−6	−5		+5	+6	+7	+8−8

The contravalencies of the left-hand groups, being originally an extrapolation from the behaviour of the right side, may be found in homeopolar compounds of the metals—*i.e.*, the alloys.

Any binary compound is unsaturated with respect to the two valencies of its components, only one kind being satisfied. The other valencies can and do act as links between binary compounds, bringing about their *molecular compounds.* The strength of their junction corresponds with the strength of the polarities present, being greater in the case of normal-valency linkage and smaller in the case of contravalencies.

This system does not claim to be a complete solution of the problem of valency; but as many known facts are in accordance with it, and may be explained by its help, it might be taken as some approximation to the truth.

(iv) *Divisibility of Valency.* *By* Professor Hugo Kauffmann.

One of the first consequences of the theory of electrons is the divisibility of valency, and chemistry furnishes us with much experimental proof of this supposition. The first investigations of this nature were made by Thiele, who as a consequence formulated a theory of partial valency. The divisibility of valency is most strikingly shown in compounds containing double bonds, and nearly all research up to the present has been developed by the aid of such bodies. The author's investigations deal with colour and fluorescence, and it has been found that in the case of benzene derivatives the colour and fluorescence of the substance becomes more marked the greater the amount of partial valency in the chromophore attached to the benzene nucleus.

These facts have peculiar signification in the case of chromophores containing

a carboxyl group. For if a salt be prepared the resulting ions are of a lighter colour, or even colourless.

Ionisation produces a redistribution of the partial valencies in such a manner that the chromophore becomes attached to the benzene nucleus with fewer valencies, and is therefore weakened as regards its colour-producing properties. The electrically charged valencies of the ions behave as free valencies, and like these are used for the saturation of other valencies. There is therefore a very close connection between chemical lines of force and electrical lines of force, the former being a consequence of the divisibility of valency and the latter of the electrical charge of the ions.

(v) *Valency.* *By* Dr. F. M. Jaeger.

(vi) *Note on the Intimate Structure of Crystals.* *By* Professor W. J. Sollas, *Sc.D., F.R.S.*

In attempting to arrive at a knowledge of the intimate structures of crystals it is essential to examine the validity of two assumptions which form the basis of certain proposed systems: one of these is the principle of closest packing, the other the notion of valency volumes. In some few cases closest packing might be regarded as highly probable; as, for instance, in that of the diamond; but such minerals, and particularly the diamond, were distinguished by exceptional properties, not the least remarkable of which is an unusually high surface tension, a peculiarity taken advantage of on the automatic separation of the diamond from its less valuable associates in the South African mines. The second assumption introduces us to an absolutely new conception, the truth of which is not self-evident but open to question.

In studies of this kind, where the constructive imagination necessarily plays a great and dangerous part, it is essential in the case of any structural system which might be proposed to show in the first place that it is not opposed by irreconcilable exceptions. This is the first step; the next, quite as essential, is to prove that no other system is capable of affording equally satisfactory results. As an example of an inconsistent fact, silver iodide may be cited, for the sudden passage of this salt from the hexagonal to the cubic system is accompanied by contraction in volume amounting to 16 per cent. Closest packing will not account for this, since the shear which is invoked to explain the transformation leaves the assemblage as close packed after the transformation as it was before. On the other hand, an open packed configuration consistent with the crystalline symmetry of the salt may be conceived, and has indeed been described, which involves of necessity a change of volume similar in amount to that observed. If this configuration should be supported by subsequent inquiry it would be sufficient of itself to destroy the universality of the two assumptions of closest packing and valency volumes, for it is based on the opposed conceptions of molecular volumes and a remarkably open packing.

As regards the structure of benzene many configurations could be devised to represent the single molecule, and before accepting any one of these it would be necessary to show that none of the others afforded equally satisfactory results. It is not a substance favourable for testing the truth of the notion of valency volumes, for it is possible that in this and most organic compounds carbon does indeed possess a molecular volume approximately four times as large as that of hydrogen. The real difficulty in this case arises when other monovalent elements are substituted for hydrogen; thus on the valency-volume hypothesis it is necessary to suppose in the case of C_6Br_6 that the volume of bromine on entering into combination diminishes from 20 to about 6, while that of carbon increases from 12 to about 24, and this although three of the bonds of each atom of carbon are united with carbon and only one with bromine. The difficulty becomes greater when compounds like $C_6H_2Br_4$ and $C_6H_4Br_2$ are taken into consideration. The molecular

volumes of benzene and its substitution products suggest a comparatively open packing, and an investigation of structure based on this suggestion is likely to afford interesting results.

FRIDAY, AUGUST 2.

Joint Discussion with Section G on Explosion Temperatures.[1]

The following Papers were read:—

1. *The Ignition Point of Gases.* *By* Professor H. B. DIXON, *F.R.S.*

2. *Iron Carbonyls.*
By Sir JAMES DEWAR, *F.R.S.*, *and* H. O. JONES, *D.Sc.*

Iron pentacarbonyl $Fe(CO)_5$ is a yellow liquid which resembles nickel tetracarbonyl in its chemical and physical properties, but it is more stable towards chemical reagents. When decomposed by reagents it always gives rise to *ferrous* salts.

The most striking difference observed between its behaviour and that of nickel carbonyl is due to the action of light, iron pentacarbonyl being decomposed with evolution of carbon monoxide and formation of an orange crystalline solid, *diferro-nonacarbonyl*, $Fe_2(CO)_9$. This change is supposed to take place in two stages, represented by

$$Fe(CO)_5 = Fe(CO)_4 + CO \text{ and } Fe(CO)_4 + Fe(CO)_5 = Fe_2(CO)_9$$

since when iron pentacarbonyl is dissolved in nickel carbonyl it is not affected by light, due, it is suggested, to the formation of an unstable compound, $FeNi(CO)_9$.

The decomposition induced by light is reversed slowly in the dark. Above 56° C. light has no action on iron pentacarbonyl: this is explained by supposing that the direct action induced by light is a change that is almost unaffected by temperature, like the reaction between ferric chloride and oxalic acid and some other photochemical actions, whereas the reverse action of carbon monoxide and the diferro-nonacarbonyl has a normal temperature coefficient.

When diferro-nonacarbonyl is heated alone a dark green liquid is produced: this consists chiefly of iron pentacarbonyl; on continued heating the green colour disappears and iron is deposited; the change is then represented by the equation $2Fe_2(CO)_9 = 3Fe(CO)_5 + Fe + 3CO$.

When substances like hydrocarbons or ether are present in excess and the temperature is not allowed to exceed 100° C. an intensely green-coloured solution is obtained; no solid is deposited, and no gas is evolved. The dark green solution under suitable conditions deposits dark green lustrous crystals which represent a third compound of iron and carbon monoxide, *iron tetracarbonyl*, $Fe(CO)_4$, which has a high molecular weight. When alcohol or pyridine is used as solvent in which to heat the diferro-nonacarbonyl the solution obtained is red, and no solid could be obtained from these solutions.

Iron tetracarbonyl is very stable towards reagents: it dissolves in most organic solvents to give dark green solutions which exhibit a characteristic absorption band in the yellow. In pyridine and alcohol, however, the colour of the solution is green at first, but changes slowly on standing and quickly on warming to a deep red; the red solutions show no selective absorption.

Both diferro-nonacarbonyl and iron tetracarbonyl when decomposed by reagents such as concentrated sulphuric acid give carbon monoxide and *ferrous* salts.

[1] Reported in *Engineering*, August 9, 1907.

3. *On the Conductivity of Electrolytes in Pyridine and other Solvents.* *By* Kenneth Somerville Caldwell.[1]

I. *Comparison of Acids and pseudo-Acids in Pyridine.*

Although previous experimenters have compared acids and pseudo-acids as regards their conductivities in solvents which form hydrogen ions (*e.g.*, alcohols and mixtures of alcohols and water[2]), no investigations have been carried out in solvents which are of such a nature that the acid is dissolved either entirely or partly in the form of a salt. Liquid ammonia would at once suggest itself as a suitable medium, more especially as a number of widely differing compounds have already been examined in this solvent,[3] but owing to the obvious experimental difficulties it was not employed. The attempt to substitute the saturated amine piperidine instead of ammonia yielded results of little interest, owing to the extremely small conductivity of solutions in this solvent. The unsaturated amine pyridine, on the other hand, proved to be more suitable.

Members of the following classes of compounds were examined:—

A. Acids which exist in one form only.

1. The strong mineral acids and sulphonic acids.
2. Organic acids.

B. Acids which exist in isomeric forms—pseudo-acids.

1. Nitro-compounds—(*a*) nitrohydrocarbons; (*b*) nitrophenols; (*c*) nitramines.
2. Oximido-compounds—(*a*) oximido-carboxylic esters; (*b*) oximido-ketones and quinonoximes; (*c*) nitrolic acids.
3. Compounds containing the group $-CO.NH-$
4. Related nitrogen compounds, *e.g.*, aminotetrazol, phenyloxytriazol carboxylic ester.
5. Ketonic-enolic compounds.
6. Oxyazobenzenes.

The pyridonium halides in pyridine exhibit the same differences in conducting power that is noticed in solutions of their alkali salts in pyridine,[4] methyl alcohol,[5] and liquid sulphur dioxide;[6] only in pyridine the difference is much more marked (*e.g.*, HCl . $\mu_{32} = 1{\cdot}16$, HBr . $\mu_{32} = 7{\cdot}12$, HI . $\mu_{32} = 27{\cdot}4$). With this exception, the 'true' acids compared among themselves follow approximately the same order in pyridine as in water; a fact which also applies to the pseudo-acids. The stronger the tendency to pass into an isomeric form, *i.e.*, the more completely the pseudo-acid form is isomerised and ionised in aqueous solution, the better does its pyridine solution conduct. There is to a certain extent a parallel between the affinity constants in aqueous solution and the conductivities in pyridine. When, however, the true acids are compared with the pseudo-acids, it is noticed that in pyridine the latter yield very much better conducting solutions than do 'true' acids, having approximately the same, or even very much greater, affinity constants. We may conclude that *when a hydrogen compound yields a pyridine solution of far better conducting power than is given by a true acid, which in aqueous solution is dissociated to approximately the same extent as the hydrogen compound, the latter is a pseudo-acid.* Hexanitrodiphenylamine, for example, must be regarded as a pseudo-acid; for although, owing to its insolubility in water, its affinity constant has not been determined, the conductivity of its pyridine solution is far greater than that of all true acids, even the strongest mineral acids.

[1] Report of work carried out in Leipzig under the direction of Professor A. Hantzsch.

[2] Hantzsch and Voegelen, *Ber.*, **35**, 1001.

[3] Franklin and Kraus, *Amer. Chem. Journ.*, **23**, 277, **27**, 196.

[4] Laszynski and Gorski, *Zeit. für Elektrochem.*, **4**, 290.

[5] Carrara, *Jahrb. für Elektrochem.*, **3**, 12.

[6] Walden and Centnerszwer, *Zeit. für Elektrochem.*, **11**, 249.

II. *On the Influence of Temperature on the Conductivity of Electrolytes.*

1. The influence of temperature on the conductivity of electrolytes may be expressed by the general equation

$$\frac{d\mu}{dt}=c\left(i\,.\,\frac{dv}{dt}+v\,.\,\frac{di}{dt}\right)$$

where i = concentration of the ions, v = mean rate of migration of positive and negative ions, t = temperature, and c = constant.

If the effect of change of temperature on the rate of migration is the reverse of that on the degree of dissociation, a maximum in the temperature-conductivity curve is to be expected.

2. It may be deduced that, for a given electrolyte, the smaller the dielectric constant of the solvent the lower must lie the temperature of maximum conductivity.

3. These deductions are confirmed by the results of previous experiments on solutions in water,[1] methyl[2] and ethyl alcohols, ammonia[3] and sulphur dioxide,[4] and especially by the results of the present investigation on solutions in pyridine. The influence of temperature on the electric conductivity of solutions in pyridine has been determined for a number of acids and pseudo-acids, as well as for silver nitrate. The temperature of maximum conductivity is well marked, and the curves have been followed up to and beyond this point.

4. The curves are represented closely by the parabolic equation $\mu_t=\mu_0(1+bt+ct^2)$ and the theoretically deduced expression $a=\frac{\mu_t-\mu_\tau}{\mu_\tau(t-\tau)^2}$ is taken as a measure of the temperature effect.

5. The observation of Walden and Centnerszwer, that for solutions in liquid sulphur dioxide the temperature of maximum conductivity is higher, the greater the conductivity, has not been confirmed for solutions in pyridine.

6. The comparatively rapid decrease in the degree of dissociation with increase in temperature may partly explain the fact that numerous substances which at ordinary temperatures yield good conducting pyridine solutions appear, according to boiling-point determinations, to be undissociated.

III. *Abnormally High Values of Ionic Conductivity.*[5]

Solutions of salts which contain either the same cation or the same anion as the solvent itself (pyridonium salts in pyridine, formates in formic acid, acetates in acetic acid, and probably bromides in hydrobromic acid and sulphates in sulphuric acid) show in these solvents an abnormally high conductivity in comparison with all other salts. Since all salts are dissociated to approximately the same extent, the abnormally high values of the conductivity of the first class can only be explained by assuming an abnormally high value for the rate of migration of those ions which the salt has in common with the solvent.

This abnormal value of the rate of migration is, however, only an apparent one. The ions of such salts react with the solvent with exchange of a labile hydrogen atom.

MONDAY, AUGUST 5.

The following Papers and Reports were read:—

1. *The Applications of Grignard's Reaction. By* ALEX. MACKENZIE, *M.A., D.Sc., Ph.D.*—See Reports, p. 273.

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[1] Noyes and Coolidge, *Zeitschr. phys. Chem.*, **46**, 323.
[2] Kraus, *Phys. Review*, **18**, 40.
[3] *Amer. Chem. Journ.*, **24**, 83.
[4] Walden and Centnerszwer, *Zeit. phys. Chem.*, **39**, 513.
[5] *Cf.* Danneel, *Zeit. für Elcktrochem.*, **11**, 249.

2. *Triphenylmethyl.* *By* Professor TSCHITSCHIBABIN.

3. *Copper Mirrors.* *By* F. D. CHATTAWAY.

The importance from the point of view of the health of the workpeople of obtaining a substitute for the tin amalgam used in the manufacture of mirrors has led many chemists to study the conditions under which metals are deposited from aqueous solution. These investigations have, however, usually had for their object the preparation of a liquid which would deposit a uniform and coherent layer of silver over a large glass surface at the ordinary temperature. Liebig was the first to solve this problem satisfactorily, and his method, in which milk sugar is the reducing agent, was formerly extensively used.

Other metals are not so easily deposited, and copper, which from its close relationship with silver one would expect to behave similarly, has never been observed to be so laid upon glass. Although copper mirrors have never been obtained by deposition of the metal from an aqueous solution, Faraday[1] about the time when silver mirrors were attracting much attention made the interesting observation that a mirror-like deposit could be obtained by dissolving a little oxide of copper in olive oil and heating plates of glass in a bath of this liquid up to the temperature at which the oil decomposes. The mirrors, however, obtained by Faraday's method, if of any size, are liable to be stained or discoloured in patches by decomposition products of the oil, and they are, moreover, generally lacking in brilliancy. Further, as the deposition of the metal only takes place when the oil decomposes, the process is excessively disagreeable to carry out; and since the oil is spoiled it is also somewhat costly.

In the course of an investigation on the oxidation of aromatic hydrazines, the author made the observation that when solutions of cupric oxide are reduced by these compounds the metal is deposited upon the glass in the form of a brilliant coherent film if clear vessels are used.

The mirrors obtained by this method are very beautiful, as they show the lustrous red colour of burnished copper, and are as perfect in reflecting surface and as uniform as the similar mirrors obtained by the deposition of silver.

It seems probable that this method of depositing copper upon glass could receive important application in the production of objects of art.

4. *Oxides of Carbon.* *By* Dr. BOUDOUARD.

The following substances are produced when carbon monoxide is heated at a temperature of 445° in the presence of a catalytic agent such as spongy platinum, nickel, or copper: (A) carbon dioxide; (B) a white crystalline substance, soluble in water, giving an acid solution; (C) a gaseous substance, soluble in water, which gives (B) on evaporation of its solution.

Similar results were obtained on submitting a mixture of carbon monoxide and hydrogen to the action of heat in the presence of a catalytic agent.

5. *Report on the Transformation of Aromatic Nitroamines and Allied Substances, and its relation to Substitution in Benzene Derivatives.* See Reports, p. 101.

6. *Report on the Study of Hydro-aromatic Substances.* See Reports, p. 104.

[1] *Phil. Trans.*, 1857, p. 145.

7. *Report on Wave-length Tables of the Spectra of the Elements and Compounds.*—See Reports, p. 116.

8. *Report on Dynamic Isomerism.*—See Reports, p. 270.

9. *Report on the Study of Isomorphous Derivatives of Benzene Sulphonic Acid.*—See Reports, p. 272.

10. *Experiments illustrative of the Inflammability of Mixtures of Coal Dust and Air.* *By* Professor P. PHILLIPS BEDSON, *D.Sc.*

11. *On Substances which form Three different Liquid Phases.* *By* Dr. F. M. JAEGER.

The results now recorded arose originally during an experimental investigation into certain theoretical objections which occurred to the author in connection with Bömer's method for detecting the adulteration of animal fats with vegetable fats. During this work the series of fatty esters of cholesterol and of Windaus's two phytosterols of Calabar fat were prepared, and the observation of the brilliant colour changes which occur on melting the cholesterol esters led to the study of the liquid phases of these substances. The colour changes in question occur with greatest brilliance with cholesteryl cinnamate, and were demonstrated to the audience.

The colour changes are due to the fact that the substances which exhibit them yield on melting several strongly doubly refracting liquid phases; the liquid phase stable at higher temperatures is always singly refracting. Lehmann showed by the microcrystallographic examination of the caproic ester that two doubly refracting liquid phases exist, and that of these one is in metastable equilibrium with the solid substance.

The author has, however, found that in the cases of a number of the esters in question three liquid phases occur, and are in perfectly stable equilibrium with the solid phase: of the three liquid phases two are doubly refracting, and consist of aggregations of liquid crystals, whilst the third is always singly refracting, but often much more viscid than the doubly refracting phases. The colour changes occur at the transition temperatures, or rather at a few degrees below those temperatures, whilst the two liquid layers are separating from each other.

The transitions of phase are in many respects analogous to those occurring with polymorphous substances, so that stable and metastable equilibria and therefore also cases of monotropy and enantiotropy occur. It is, however, remarkable that a new kind of equilibrium is observed with these substances; this the author terms 'prostable equilibrium.' A prostable phase resembles a metastable phase in that both can be experimentally realised only as the result of a temperature change in one direction; the two kinds of phase differ in that the prostable phase can only be obtained as a result of raising the temperature. The formation of a prostable phase therefore occurs before and after that of the stable phases during a rise of temperature. This was demonstrated to the audience with the aid of cholesteryl laurinate and illustrated by means of the vapour-tension curve of the ester.

With some of these esters the author has further observed that the solid phase can be heated to above the melting-point without melting; cholesteryl laurinate can thus be heated to five degrees above the highest transition temperature without the solid phase entirely disappearing. Similar retardation phenomena occur in other cases, and their occurrence can be conveniently illustrated by means of the vapour-tension curves of the a-phytosterol esters.

12. *Calcium: its Properties and Possibilities.* *By* Arthur E. Pratt, *B.Sc.*

General Properties.—Calcium is a silvery white metal readily oxidised in moist air. It is very light (sp. gr. 1·52), fairly malleable, has a high specific heat, and is a good conductor of electricity. It is about as hard as aluminium, but at 400° C. becomes as soft as lead. It is volatile, and can be sublimed *in vacuo* between 700° C. and 800° C., and melts at the latter temperature. It is a very powerful reducing agent.

Calcium Alloys.—The chief effects of alloying calcium with other metals are to produce brittleness, crystallisation, and hardness; to promote oxidation and disintegration on exposure to air; to confer the power of decomposing water and in other ways increasing the chemical activity.

The author's experiments confirm Roberts-Austen's observation that the presence of small amounts of metals of high atomic volume will cause deterioration of the physical properties of metals of low atomic volume. The atomic volume of calcium is high (25·4), and the effect of small amounts on other metals is decidedly prejudicial, provided that the metals in question are pure. The experiments were conducted in a converse manner to Roberts-Austen's, *i.e.*, the constant was a metal of high atomic volume (calcium) instead of being low (gold). In the course of the work the following observations were made: When an alloy is made of calcium and some metal which possesses a chemical property in common with it, an increased activity in the manifestation of that property is noticed in the alloy. This increase appears to be greater than would be obtained by the simple admixture of a more active metal, the presence of calcium usually increasing the activity of the other metal. In some cases the alloy is more active than either of its constituents.

Further, the chemical properties of calcium appear to be more pronounced in an alloy with a metal having an atomic volume closely approaching that of calcium than they are in an alloy of the same percentage with a metal having a much lower atomic value. The two metals in question should be about equally active when unalloyed in the particular property with respect to which they are to be compared.

It is probable that both these principles are general, and not confined to calcium, although more extended research on these lines would be desirable.

Industrial Possibilities.—The most promising applications of calcium are as a reducing agent and for the refining of metals. In the latter case it acts in three distinct ways: (1) By reducing oxides and sulphides; (2) by eliminating dissolved gases; (3) by forming compounds with certain impurities, thus rendering them less deleterious. All three modes of action are strikingly shown in the case of copper. A suitable addition of calcium will remedy 'dry' or 'sulphury' copper, give a sound casting, and give a soft and tough ingot with prohibitive proportions of bismuth or antimony, besides restoring ordinary overpoled copper to tough pitch. If excess of calcium is present, however, it induces brittleness on its own account.

With one or two doubtful exceptions, no alloy of calcium has shown any promise of commercial utility so far as physical properties are concerned, its only likely application in this direction being its hardening property.

TUESDAY, AUGUST 6.

Discussion on the Chemistry of Wheat and Flour, with Special Reference to Strength.

(i) *Causes of the Quality Strength in Wheaten Flour.* *By* A. E. Humphries.

The Home-grown Wheat Committee of the National Association of British and Irish Millers has for several years been engaged in producing wheats in England

which shall yield maximum crops of grain and straw, the wheat to be equal in strength, and therefore in commercial value, to the best imported varieties.

The field of inquiry has been a wide one, and among other things the Committee has sought to ascertain 'the ultimate cause of strength in wheat, the nature and source of those constituents which confer on some varieties of wheat the inherent quality of strength, and the power of transmitting it to succeeding generations.' It has been proved that though climate and soil influence quality, they are not the determining factors in the production of strength, for though the strongest wheats are ordinarily produced in districts where the winters are cold, the summers hot, and the summer rainfall high, certain varieties possess and retain the inherent quality of strength when grown in England. Manuring or early cutting at harvest time has no beneficial effect on quality. Quick growth or rapid maturation of wheats grown in England is not correlated with strength, nor does the percentage of natural moisture in well-harvested wheat indicate it; indeed in certain cases the addition of water to wheat materially increases its effective baking strength.

The term 'strength' has been loosely applied to cover several characteristics. In the view of the Committee it should not be measured by the quantity of water required to make doughs of a standard consistency, nor by the quantity of bread produced per sack of flour used, nor by the way a flour behaves in the dough, but by its capacity for making big, shapely, and therefore well-aërated loaves. This definition covers two characteristics: one, a flour's capacity for making gas in yeast fermentation, more particularly its capacity for making gas at the latest stages of fermentation; the other, its capacity when made into dough for retaining the gas so generated.

The gas-making power will depend largely on the percentage of natural sugar any given wheat contains and its diastatic capacity. These characteristics vary substantially in different wheats. The baker can, and does, influence the quantity of gas generated in baking. The retention of gas when made involves complex problems.

The percentages of total nitrogen, gluten, gliadin, and amyloids do not correctly indicate the relative strengths of various flours. The theory that strength depends on a correct ratio between gliadin and glutenin is untenable. Professor Wood's suggestion that the strength of flour depends on its ratio of protein to salts is worthy of the closest attention in view of the fact that the physical, as distinct from the chemical, properties of proteins are profoundly affected by small quantities of acids, alkalies, and salts.

(ii) *Some Considerations determining the Strength of Flours.* *By* J. L. BAKER *and* H. F. S. HULTON.

H. B. Wood recently described[1] a chemical test for 'strength' in flours, which depended on the amount of CO_2 liberated from a dough under standard conditions. The volume of CO_2 liberated in most instances was proportional to the baker's marks assigned to the flour, although there were exceptions. It was assumed that the quantity of CO_2 liberated depended upon the diastatic power of the flour and the ready-formed carbohydrates present. The authors do not think a correlation of diastatic power and ready-formed carbohydrates is justified in the present state of our knowledge, for nothing has yet been published concerning the nature of the diastase in wheat. In view of the fact that the diastatic power of wheat is a possible factor to be considered in connection with strength of flour, the authors have investigated the diastase of wheat. It has been previously shown[2] that the diastase of barley is very different from that of malt, and in an investigation shortly to be published, in conjunction with F. E. Day, the authors find that the action of wheat diastate on wheat starch is similar in character to the action of barley diastase. At a temperature of 50° C. maltose and one dextrin (a-amylodextrin) only are produced, and this will have

[1] *Nature*, 1907, **75**, 391.
[2] J. L. Baker, *Journ. Soc. Chem.*, 1902, **81**, 1177.

some bearing when the chemical composition of baked bread comes under consideration. Kjeldhal's 'Law of Proportionality' holds within certain limits with wheat diastase; so if the diastatic power is determined by Lintner's method the results are comparable. The diastatic powers have been measured of a number of flours of known baking value which were kindly supplied by Mr. A. Humphries. In some instances a high baking value is accompanied by a high diastatic power, but the exceptions are so marked that no conclusions can be drawn. Moreover, the diastatic power varies materially on keeping the flour. For example, a series of flours of diastatic powers of 23°, 22°, and 17° in two months became 32°, 29°, and 28°. The converse also holds for a series of diastatic powers: 31°, 32°, and 35° became 22°, 28°, and 20° in the same time. In this connection it may be pointed out that barleys and malts behave similarly. It is also well known that certain flours improve in strength on keeping. At the ordinary temperature the diastase in flour does not materially act on the starch, so that the amount of ready-formed sugars existing in the flour may be fairly accurately measured by aqueous extraction for two hours. But at the temperatures of 30° to 40° C. a considerable quantity of maltose is formed. As this maltose, together with the ready-formed sugars, is used up by the yeast, it is fair to conclude that diastase is an important factor in the raising of the dough. In normal flours there is an excess of diastase, so whether its activity varies between 20° and 35° Lintner, there is more than enough to produce a certain amount of maltose from the starch during the making of the dough. For this reason a determination of the diastatic activity is not likely to afford any evidence as to the baking value of a flour.

Sugars.—The total sugars, after inversion of the cane sugar present calculated as glucose, vary from 1·6 to 2·4 per cent. The reducing sugar present in cold aqueous extract of flour—not taking into account the maltose formed by the action of diastase during extraction—appears to consist of a mixture of invert sugar and glucose. The percentages of sugar in different flours do not point to any connection with the baking value.

So far it is not possible to judge of the baking value of a flour by determining any one factor, such as total gluten, ratio of gliadin to glutenin, diastatic power, or ready-formed sugars. H. B. Wood suggests that the difference between strong and weak flours is connected more with the physical properties of their glutens than with the chemical composition, and he proposes to investigate the effect of the addition of small quantities of acids, alkalies, and salts. This should yield interesting results, for the character of enzyme change is greatly affected by the addition of such substances.

A hopeful line of investigation seems to be afforded by the study of other enzymes than diastase which may be present. Such observations as the destruction of wheat for flour-making purposes by sprouting or the presence of SO_2 in the holds of vessels, the marked improvement by holding over flours and the grading of flours of different origin to improve the baking value, all appear to us to indicate enzymic activity. The authors are at present examining flours for enzymes other than diastase, and a proteolytic enzyme has been detected which acts on the white of egg. This doubtless has some bearing on the question, for the proteolytic enzyme may possibly effect an alteration in the physical properties of the gluten and modify its capacity for gas retention. It seems likely that it is the variation in the capacity of flours for gas retention rather than absolute volume of gas formed which differentiates strong from weak; and the gas which effects the final volume of the loaf is, it can hardly be doubted, the CO_2 from the maltose formed by the action of the diastase on starch rather than the gas from the ready-formed sugars.

The following Paper was then read:—

1. *The Production of Acid or Alkaline Reactions in the Soil by Artificial Manures.* *By* A. D. HALL, *M.A.*

Section C.—GEOLOGY.

President of the Section.—Professor J. W. Gregory, D.Sc., F.R.S.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

I. *The Geological Society of London.*

1907! This is the centenary year of the Geological Society of London; next month the British geologists will celebrate the event, and their pleasure will be enhanced by the sympathetic presence of a distinguished company of foreign geologists.

With a just feeling of satisfaction may we celebrate this event; for to the Geological Society of London is due the conversion of Geology from a fanciful speculation to an ordered science. Yet so quietly has this society done its work that the debt due to it is inadequately realised. When we consider what the world owes to Geology in respect of its economic guidance—the intellectual stimulus of its conceptions—the reverence it inspires for the venerable and majestic universe—its liberating influence from dogma—we may rightly regard the work of the Geological Society, as one of the most valuable British contributions to intellectual progress during the nineteenth century.

A hundred years ago the spirit of the eighteenth century still controlled much of the then orthodox Geology. Jameson's 'Elements of Geognosy,' of which the preface is dated January 15, 1808, taught, as the certain conclusions of Geology, doctrines that had been reached by applying prejudiced speculation to imaginary facts. It was a manual of pure, *a priori*, Wernerian Geology. The author claimed that to Werner 'we owe almost everything that is truly valuable in this important branch of knowledge'; and that it was Werner 'who had discovered the general structure of the crust of the globe and pointed out the true mode of examining and ascertaining those great relations which it is one of the principal objects of geognosy to investigate.'

But Jameson's book was the death-song of Wernerian Geology in British science. A new Geology was developing; and the Geological Society of London ushered in its birth. No more should observations be made through the distorting medium of preconceived fancies! No more should Geology be inspired by that heedless spirit, which cares not to distinguish between fancy and fact! With youthful vigour the new Geology would have nothing to do with the search for cosmogonies and such like fancy foods; and the Geological Society of London should be nourished on unadulterated facts.

The time was ripe for the change. No less a person than Goethe, once an enthusiastic votary of Geology, was, in his play of 'Faust,' holding up its teachers to ridicule. The theories 'evolved from the inner consciousness' of Continental Neptunists and Plutonists were to Goethe excellent subjects for caricature. It was then the Englishman, Greenough, founded a society to turn Geology from the pursuit of fleeting fancies and lead her to the study of sober

but enduring facts. The members of this society were to abandon the quest of scientific chimæras; they were to leave to later generations the attempt to solve the universe as a whole.

The Geological Society has owed its influence to its bold, original purpose. It was not founded as a drifting social union of men, with a common interest in a single science. Its object was to apply to Geology one particular mode of research. It adopted as its motto this fine passage from Bacon:—

'If any man makes it his delight and care—not so much to cling to and use past discoveries, as to penetrate to what is beyond them—not to conquer Nature by talk, but by toil—in short, not to have elegant and plausible theories, but to gain sure and demonstrable knowledge; let such men (if it shall seem to them right), as true children of knowledge, unite themselves with us.'

The methods of the society were as practical as its ideals. London, with characteristic unconventionality and originality, has used its scientific societies as its university for post-graduate teaching. Informally the Geological Society enrolled every British master of Geology on its staff of unpaid professors, then set each of them to teach the branch of Geology which he knew best. And these professors were no carpet knights; they were knights errant who derived their knowledge, not from books alone, but from their wanderings over hills and dales, in mines and quarries, by ice-polished rocks and water-worn valleys. At its meetings the leaders of the society announced what they had discovered, gave sure and demonstrable proofs of their discoveries, and showed in what direction the geological forces should be directed for the conquest of Nature. The goodly fellowship of the Geological Society has always encamped on the ever-advancing frontier of geological knowledge, where the well-surveyed tracks pass out into the bright, alluring realms of the unknown.

The actual founders of the Geological Society were apparently men of less showy intellect than the great Werner, whose teaching had intoxicated many of the most gifted of his enthusiastic pupils. They were men, like Greenough and Phillips, who had a practical insight that enabled them to give a permanent help to the progress of science. They had that supreme gift, the power to see things as they are. It would not be fair to claim for them that they were the originators of accurate methods in Geology; such methods had been used before their day—by William Smith in England, by Lehman in Germany, and by Desmarest in France. But these men, acting singly, had not been able to save Geology from the eighteenth-century spirit of adventurous speculation, nor had they lifted from Geology the burden of those quaint theories, that made this science the butt of Voltaire's luminous ridicule.

The great achievement of the Geological Society has been this: as a corporate body it has been able to spread its influence very widely; its clear-sighted pursuit of a practical ideal has been adopted in other countries; its resolute rejection of the temptation to wander in dreamland has affected geological students all over the world. In this way has been laid a broad foundation of positive knowledge upon which modern Geology has been built.

The fine self-restraint, which induced the founders of the Geological Society to restrict its work for awhile to observing the surface of the earth, has had its reward. The methods this society was founded to employ have been so widely used, that we now have geological maps of a wider area than was known to geographers of a century ago. The general distribution of all the rocks on the earth's surface has been discovered; most settled countries have been surveyed in some detail; the main outlines of the history of life on the earth have been written and carried back almost as far as palæontologists are likely to go. There are doubtless fossiliferous areas still undiscovered in the 'back blocks' of the world; but, though negative predictions are proverbially reckless, it seems probable that Palæontology will not carry geological history materially farther back. Fossils have been discovered in the præ-Cambrian rocks; the best known is the fauna described by Walcot from Montana; but his Beltina, the oldest well-characterised fossil, is still of Palæozoic type. It may be that the poverty

of carbonate of lime, which is so characteristic a feature of most Cambrian and præ-Cambrian sediments, indicates that the bulk of the contemporary organisms had chitinous shells or were soft-bodied. Palæontology begins with the appearance of hard-bodied organisms; it can only reveal to us the dawn of skeletons, not the dawn of life. We are dependent for knowledge of the climate and geography of Eozoic time to the evidence of the sediments, of which there are great thicknesses beneath the fossiliferous rocks in most parts of the world.[1]

II. *The Geology of the Inner Earth.*

Now that this geological survey of the earth is in rapid progress; while the history of life has been written at least in outline; the chief fossils, minerals, and rocks have been described and generously endowed with names; and the manifold activity of water and air in moulding the surface is duly appreciated, it is not surprising to find that the centre of geological interest is shifting to the deeper regions of the earth's crust and to the problems of applied Geology. The secrets of these deeper regions are both of scientific and economic interest. They are of scientific importance, for it is now generally recognised that the main plan of the earth's geography and the essential characters of the successive geological systems are the result of internal movements. The relative importance of those restless external agents that we can watch, denuding here and depositing there, has been exaggerated; probably they do little more than soften the outlines due to the silent heavings produced by the colossal energies of the inner earth.

The study of the deeper layers of the crust is of economic interest, for, with keener competition between increasing populations and with the exhaustion of the most easily used resources of field and mine, there is growing need for the better utilisation of soils and waters, and for the pursuit of deeper deposits of ore.

If a shaft be sunk at any point on the earth's surface, a formation of Archæan schists and gneisses would probably always be reached; and, working backward, geological methods always fail at last—in primæval, Archæan darkness. The Archæan rocks still hide from us the earlier period of the earth's history, including that of all rocks which now lie beneath them. But already there are indications that the mystery of the 'beyond' is not so impenetrable as it seemed.

1. *The Nebular and Meteoritic Hypotheses.*—The eighteenth century explained the history of the earth by the nebular hypothesis of Laplace. Geologists respectfully adopted this idea from the astronomers; they accepted it as one of those essential facts of the universe with which geological philosophy must harmonise. The resulting theory represented the earth as originally a glowing cloud of incandescent gas, which slowly cooled, until an irregular crust of rock formed around a gaseous or molten core; as the surface grew cooler, the depressions in the crust were filled with water from the condensing vapour, forming oceans which became habitable as the temperature further fell. The whole earth was thought to have had a long period with a universal tropical climate, under which coral reefs grew where flow our polar seas, and palms flourished on what are now the Arctic shores. Still further cooling had established our climatic zones; and it was predicted that in time the polar cold would creep outward, driving all living beings toward the equator, until at length the whole earth, like the moon, would become lifeless through cold, as it had once been uninhabitable through heat. This theory has permanently impressed itself on geological terminology; and its corollaries, secular refrigeration and the contortion of the shrinking crust, once dominated discussions concerning climatic history and the formation of mountain chains. This nebular hypothesis, however, we are now told, is mathematically

[1] Such are the Algonkian sediments represented by the Huronian and Algonkians of America, the Algonkians of Scandinavia, the Karelian of Finland, the Briovarian of North-West France, the Heathcotian of Australia, the Transvaal and Swaziland systems of South Africa, the Dharwar and Bijawar systems of India, the Itacolumnite series of Brazil, &c.

improbable, or even impossible; and it is only consistent with the facts of Geology on the assumption that, in proportion to the age of the world, the whole of geological time is so insignificant that the secular refrigeration during it is quite inappreciable; hence Geology can no more confirm or correct the theory than a stockbreeder could refute evolution by failing to breed kangaroos into cows in a single lifetime.

The theory of the gaseous nebula has been probably of more hindrance than help to geologists; its successors, the meteoritic hypothesis of Lockyer and the planetismal theory of Chamberlin, are of far more practical use to us, and they give a history of the world consistent with the actual records of Geology. According to Sir Norman Lockyer's meteoritic hypothesis, nebulæ comets and many so-called stars consist of swarms of meteorites which, though normally cold and dark, are heated by repeated collisions, and so become luminous. They may even be volatilised into glowing meteoritic vapour; but in time this heat is dissipated, and the force of gravity condenses a meteoritic swarm into a single globe. Some of the swarms are, says Lockyer, 'truly members of the solar system,' and some of them travel around the sun in nearly circular orbits, like planets. They may be regarded as infinitesimal planets, and so Chamberlin calls them planetismals.

The planetismal theory is a development of the meteoritic theory, and presents it in an especially attractive guise. It regards meteorites as very sparsely distributed through space, and gravity as powerless to collect them into dense groups. So it assigns the parentage of the solar system to a spiral nebula composed of planetismals, and the planets as formed from knots in the nebula, where many planetismals had been concentrated near the intersections of their orbits. These groups of meteorites, already as solid as a swarm of bees, were then packed closer by the influence of gravity, and the contracting mass was heated by the pressure, even above the normal melting-point of the material, which was kept rigid by the weight of the overlying layers.

This theory has the recommendation of being consistent with the history of the earth as interpreted by Geology. For whereas the nebular hypothesis represents the earth as having been originally intensely hot, and having persistently cooled, yet geological records show that an extensive low-level glaciation occurred in Cambrian times in low latitudes in South Australia;[1] indeed, it seems probable that, in spite of many great local variations, the average climate of the whole world has remained fairly constant throughout geological time. Whereas it has often been represented, in accordance with the nebular theory, that volcanic action has steadily waned, owing to the lowering of the earth's internal fires and the constant thickening of its crust, yet epochs of intense volcanic action have recurred throughout the world's history, separated by periods of comparative quiescence. Whereas it has been assumed, as a corollary to the nebular theory, that the force which uplifted mountain chains was the crumpling of the crust owing to the contraction of the internal mass, yet observation reveals that the crust has been corrugated, and fold mountains formed by contraction to an extent far greater than secular cooling can explain.

2. *The Materials of the Inner Earth.*—This planetismal hypothesis is not only consistent with geological records, but also with the known facts as to the internal composition of the earth and the structure of extra-terrestrial bodies as revealed by meteorites. Meteorites are of two main kinds—the meteoric irons, which consist of nickel iron, and stony meteorites, which are composed of basic minerals. Some of the stony meteorites have been shattered into fault breccias, showing that they are fragments of larger bodies which were subject to internal movements, like those that have formed crush-conglomerates in the crust of the earth. Those stony meteorites, therefore, both in composition and structure resemble the rocks in the comparatively shallow fracture zone of the earth's crust. The nickel-iron meteorites, on the other hand, represent the barysphere beneath the crust.

The earth appears to consist of material similar to that of the two types of meteorites; but whether the proportions of the two materials in the earth represent

[1] As shown by the work of Professor Howchin, of Adelaide.

their proportions in other bodies and in meteoric swarms is problematical. There appear to be no satisfactory data for an estimate of the relative abundance in space of the iron and stony meteoric material. Stony meteorites have been seen to fall far more frequently than iron meteorites; but the largest known meteorites are of the nickel-iron group, although this material, in moist climates, very soon decays. The most reliable indication as to the relative amounts of the stony and nickel-iron meteorites is given by a comparison of the weight of the two types of material in meteorites of which the fall was seen. According to Mr. Fletcher's list of the meteorites in the British Museum up to 1904, the collection included 319 specimens of which the fall is recorded: of them 305 specimens were stony meteorites of an average weight of 2·63 lb., 9 were iron meteorites of an average weight of 2·31 lb., and 5 were siderolites (or meteorites containing a large proportion of both silicates and nickel iron) of an average weight of 54 lb.[1] Therefore, according to this test, the stony materials would appear to be the more abundant. But if all known meteorites are considered, the iron group far outweighs the other; for the iron meteorites in the British Museum collection weighed 11,873 lb., as against a total weight of only 865 lb. of stony meteorites. The available evidence suggests that the stony meteorites fall the more frequently on the earth, but the meteoric irons come in such large masses that they outbalance the showers of the smaller stones.

We might have expected help from another source in examining what lies below the Archæan rocks. Cannot the relative proportions of the stony and metallic constituents in the earth help us? Unfortunately, this proportion is as uncertain, as that of stony and iron meteoritic material. The best-established fact about the interior of the earth is that its materials are much heavier than those of its crust. The specific gravity of the earth as a whole is about 5·67; the specific gravity of the materials of the crust may be taken as about 2·5, while that of the heavier basic rocks is only about 3·0. Hence the earth as a whole weighs about twice as much as it would do, if it were built of materials having the same density as those which form the crust.

Two explanations of the greater internal weight of the earth have been given. According to one, the earth is composed throughout of the same material, and the internal mass is only heavier because it is compressed by the weight of the overlying crust. Laplace estimated that the material would gradually increase in density from the surface to the centre, where its specific gravity would be 10·74, and the calculations of Schlichter show that condensation due to compression may be adequate to account for the greater internal weight.

According to the alternative or segregation theory, the difference in density is explained as due to a difference in composition; the interior of the earth is thought to be heavier owing to the concentration of metals within it. The probability of this metallic interior has been advanced from several lines of evidence; and the assumed metallic mass has received from Posepny the name of the 'barysphere,' or heavy sphere. According to this view the earth is essentially a huge ball of iron, which, like modern projectiles, is hardened with nickel; and it is covered by a stony crust, the materials of which were primarily separated from the metallic mass, like the slag formed on a ball of solidifying iron in a puddling furnace.

It has been objected that the weight of the earth is not great enough for muc of it to be composed of metallic iron or of meteoritic material. The specifi gravity of iron under the pressure at the earth's surface is about 7·7, and it woul be even greater when compressed in the interior. But the barysphere is doubtles impregnated with much stony material that would lessen its weight. A estimate by Farrington (1897) of the average specific gravity of the meteorit of which the fall had been recorded is only 3·69. According to the Rev. I Hill (1885) the mean specific gravity of all the meteorites in the British Museu

[1] The weights are given in pounds avoirdupois. For the calculation I a indebted to Mr. W. R. Wiseman, of the Geological Department of Glasg University.

was 4·5; and, though Mr. Hill duly considered the effect of compression, he concluded that 'the density of the earth is perfectly consistent with its being an aggregation of meteoric materials.' Moreover, within the metallic barysphere there may be a core of lighter material; for earthquake waves travel more slowly in the central core of the earth than in the intermediate zone, or are even suppressed altogether there; hence the centre of the earth may be occupied by matter less compact than that of the shell around it; and, according to Oldham's calculations, the light central core occupies two-fifths of the diameter of the earth.

The evidence of density alone, therefore, gives no convincing evidence of the nature of the earth's interior; and geologists have been left with no conclusive reason for choosing between the condensation and segregation theories. Radio-activity has, however, unexpectedly come to our aid, and has disclosed a further striking resemblance between the internal mass of the earth and the iron meteorites. It has supplied direct evidence about the constituents of the earth at depths which have hitherto been far beyond the range of observation. Mr. Strutt has shown that radium is probably limited within the earth to the depth of 45 miles; that the deeper-lying material is free from radium; and that this substance is not found in iron meteorites.

The agreement in radio-active properties between the iron meteorites and the interior of the earth is an additional and weighty argument in favour of the view that the earth is largely composed of nickel iron.

3. *Physical Conditions and Temperatures.*—The physical condition in which the material exists is now of secondary interest. The old controversy as to whether the earth has a molten interior inclosed within a solid shell has lost its importance, because it has become a mere matter of definition of terms. The facts which led geologists to believe that the interior of the earth is fluid are consistent with those which prove that the earth is more rigid than a globe of steel. For under the immense pressure within the earth the materials can transmit vibrations and resist compression like a solid; but they can change their shape as easily as a fluid. They are fluid just as lead is when it is forced to flow from a hydraulic press. Not only are geologists now justified in their belief that the deeper layers of the earth's crust are in a state of fluxion, but, according to Arrhenius (1900), the earth is solid only to the depth of 25 miles, below which is a liquid zone extending to the depth of 190 miles; and below that level, he tells us, 'the temperature must, without doubt, exceed the critical temperature of all known substances, and at this depth the liquid magma passes gradually to a gaseous magma.' This distinguished physicist gives a description of the earth's interior which reminds us of the views of the early geologists. Arrhenius's theory rests, however, on the existence within the earth of exalted temperatures; and this assumption a geologist may now hesitate to accept with less risk of getting into disgrace than he would have run a few years ago. It is improbable that the rapid increase of heat with depth which is observed near the surface should continue below the lithosphere; for, if the earth consists in the main of iron, even although it be arranged as a mesh containing silicates in the interspaces, the heat conductivity might be sufficient to keep the whole metallic sphere at a nearly equal temperature. Here, again, Mr. Strutt's work on radio-activity is in full agreement with the requirements of geologists, for he estimates that below a crust 45 miles thick the earth has a uniform temperature of only 1500° C. Whether the further conclusion, that this heat is due to the action of the radium in the crust, be established or not, it is gratifying to hear a physicist arguing in favour of a moderate and uniform internal temperature.

All that the actual observations prove and that geological theories require is that the material within the earth be intensely hot, and that it lie under such overwhelming pressure that it would as readily change its form and as quickly fill up an accessible cavity as any liquid would do. Whether such a condition is to be described as solid, liquid, or gaseous is of little concern to geologists.

III. *The Deep-seated Control over the Earth's Surface.*

The modern view of the structure of the earth adds greatly to the interest of its study, for it recognises the world as an individual entity of which both the geological structure and the history have to be considered as a whole. Once the earth was regarded as a mere lifeless, inert mass which has been spun by the force of gravity that hurls it on its course, into the shape of a simple oblate spheroid. Corresponding with this astronomical teaching as to the shape of the world was the geological doctrine, that all its topography is the work of local geographical agents, whose control over the surface of the earth is as absolute as that of the sculptor's chisel over a block of marble.

Both these conceptions are now only of historic interest. The irregular individual shape of the earth is expressed by its description as a geoid. The processes which have produced its varying shape have also controlled its geological history and evolution, for they cause disturbances of the crust, which affect the whole earth simultaneously; and so the geographical agents are given similar work and powers at the same time in different places.

Hence there is a remarkable world-wide uniformity in the general characters of the sedimentary deposits of each of the geological systems. The last præ-Cambrian system includes thick masses of felspathic sandstones alike in the Torridonian of Scotland, the sparagmite of Scandinavia, the Keweenawan Sandstones of the United States, and perhaps also the quartzites of the Rand. The Cambrian has its greywackes and coarse slates and its numerous phosphatic limestones; the Ordovician its prevalent shales and slates; the Silurian its episodal limestones and shales. The Devonian has its wide areas of Old Red Sandstones as a continental type, while its marine representatives show the prevalence of coarse grits and sandstones in the lower series, of limestones and slates in the middle series, and the recurrence of sandstones in the upper series; and this sequence occurs alike in North-Western Europe, in America, and Australia. The Carboniferous contains the first regional beds of thick limestone and the first important Coal Measures. The Trias contains rocks indicating the same arid continental conditions in America, Australia, Asia, and Africa that Professor Watts has shown then prevailed in the neighbourhood of Leicester. In the Mesozoic era we owe to Suess the demonstration of the world-wide influence of those marine encroachments or 'transgressions' whereby the great continents of the Trias were gradually submerged by the rising sea.

Speaking generally, there is a remarkable lithological resemblance between contemporary formations in all parts of the world. This fact had been often remarked, but was usually dismissed as due to a number of local isolated coincidences of no special significance. But the coincidences are too numerous and too striking to be thus lightly dismissed. They are among the indications that the main earth-changes have been due to world-wide causes, which led to the predominance of the same types of sedimentary rocks during the same period in many regions of the world.

The conditions that govern the geological evolution and general geography of the earth are probably due to the interaction between the earth's crust and the contracting interior; they may take place as slow changes in the form of the earth, causing the slow rising or lowering of the sea surface, or the slow uplift or depression of regions of the earth's crust; or they may give rise to periods of violent volcanic action in many parts of the earth, between which may be long periods of quiescence. The geographical effects of changes in the earth's quivering mass affect distant regions at the same time. Therefore the landmarks of physical geology will probably be found to give more precise evidence as to geological synchronism than those of Palæontology, on which we have hitherto had to rely.

IV. *Plutonists and Ore-formation.*

Belief in the earth's internal fires was most faithfully held amongst geologists by the Plutonists of the eighteenth century, and repudiated with

equal thoroughness by the Neptunists, who refused to concede that volcanic action was due to deep-seated cosmic causes. Thus Jameson in 1807 stoutly maintained that volcanoes were superficial phenomena due to the combustion of beds of coal beneath fusible rocks, such as basalt, and that the explosions were due to the sudden expansion of sea-water into steam by contact with the burning coal. Volcanoes, according to this view, were correctly described as burning mountains, giving forth fire, flame, and smoke. The extreme Neptunist and Plutonist schools have long since been extinct, but the controversy is not quite closed. The battlefield is now practically restricted to economic geology, and the issue is the origin of some important ores.

Ore deposits present so many perplexing features that deep-seated igneous agencies were naturally invoked to explain them, and some of the most thorough-going champions of the igneous origin of ores make claims that remind us of the eighteenth-century Plutonists. The question is to some extent a matter of terms. Many of the ores which Vogt, for example, describes as of igneous origin he attributes, not to the direct consolidation of material from a molten state, but to eruptive after-actions due to the hot solutions and heated gases given off from cooling igneous rocks. Igneous rocks probably play a notable part in the genesis of most primary ore deposits; for the entrance of the hot ore-bearing solutions is rendered possible by the heat of the igneous intrusions, as Professor Kemp has well shown in his paper on 'The Rôle of Igneous Rocks in the Formation of Metallic Veins.' Professor Kemp limits the term 'igneous' to materials formed by the direct consolidation of molten material; and this decision seems to me to be most convenient. For example, the quartzite that is so often found beneath a bed of basalt is due to hot alkaline water from the lava cementing the loose grains of sand; the process is an eruptive after-action, but it would be unusual to call such a quartzite an igneous rock.

1. *Igneous Ores.*—That there are ores which are the products of direct igneous origin is now almost universally admitted. The mineral magnetite is a most valuable source of iron, and it is a constituent of most basic igneous rocks. If iron were a high-priced metal, such as tin or copper, of which ores containing one or three per cent. are profitably worked, then basalt would be an ore of igneous origin. Under present commercial conditions, however, basalt cannot be regarded as an iron ore. But if the magnetite in a basic rock had been segregated into clots or masses large enough and pure enough to pay for mining, then they would be iron ores formed by igneous action. There are cases of such segregations large enough to be mined. The most famous is Taberg, a mountain in Småland, near the southern end of Lake Wetter, in Sweden. It is a locality of historic interest; a view of it, as a mountain of iron, was published by Peter Ascanius [1] in the 'Philosophical Transactions' in 1755, and the element vanadium was first discovered in its ore by Sefström in 1830.

Taberg consists of an intrusive mass of rock composed of magnetite, olivine, labradorite, and pyroxene. Many theories of its formation have been advanced. The view generally adopted is that of Törnebohm, who described the rock as a variety of hyperite in which there has been a central segregation of magnetite to such an extent, that some of it contains 31 per cent. of iron. Törnebohm claims to have traced a gradual passage from normal hyperite to a variety poor in felspar, then to one without felspar, and finally to a granular intergrowth of magnetite and olivine. This Taberg ore was mined and smelted for iron in the eighteenth century, when transport was more costly and commercial competition less keen than it is to-day. The ore has been worked at intervals as late as 1870; and as the hill is estimated to contain 100 million tons of ore above the level of the adjacent railway, it is not surprising that efforts are being again made to utilise the deposit, in spite of its low grade and high percentage of titanium. The Taberg rock has almost reached the line which divides magnetite-bearing rocks from useful iron ores. Its igneous origin, however, has not been universally accepted. The theory has been rejected by so eminent an authority as Posepny,

[1] Vol. xlix. pp. 30–34, pl. ii.

according to whom the ore occurs in solid veins as well as in grains; and he holds that, like other Scandinavian iron ores, it was due to secondary deposition. During a visit to the mountain, I failed to see any secondary veins, except of insignificant value. The microscopic sections of the ore show that it is a granular aggregate of olivine, generally with labradorite and pyroxene. Hence I have no hesitation in accepting the view of the Swedish geologists and regard Taberg as a magmatic segregation. Posepny [1] has in this case carried his Neptunist theory of the genesis of ores too far.

At Routivaara, in Swedish Lapland, there is a still larger mass of magnetite, which is claimed, in accordance with the descriptions of Petersson and Sjögren, to be due to segregation from the magma of the surrounding gabbro. This mass of magnetite is of colossal size, but it is of no present economic value, owing to its high percentage of titanium and its remote position.

An igneous origin is claimed by Professor Högbom for some small masses of titaniferous magnetite in the island of Alnö, opposite Sundsvall, on the eastern coast of Sweden. This case is of interest, as the surrounding rock is not basic: it is a nepheline syenite, containing only 2 per cent. of magnetite, which, however, has been concentrated in places, until some specimens (according to an analysis quoted by Professor Högbom) contain as much as 64 per cent. of magnetite, 9 per cent. of ferrous oxide, and 12 per cent. of titanic oxide.

The Alnö magnetites, again, are of no practical value, as they are too low in grade and too refractory in nature. I understand that about 500 tons of the material have been smelted, but with unprofitable results, and the rest of the material quarried has been left on the shore. We may therefore accept the iron-bearing masses of Alnö and Routivaara, as well as that at Taberg, as due to magmatic segregation, without having conceded much as to the igneous formation of ores. The process in this case has formed rocks, rich in titaniferous magnetite, from which iron could be obtained, but rocks which no ironmaster is at present willing to buy as iron ore. Whether a basic igneous rock is to be regarded as an iron ore, or as only useful for road metal, depends on cost of treatment. The definition of the term 'ore' is very elastic. Petrographers speak of the minute grains of magnetite or chromite in a rock as its ores; but that is a special use of the term 'ore.' Usually ore means a material which can be profitably worked as a source of metals under existing or practicable industrial conditions.[2] According to this definition, the Swedish deposits of titaniferous magnetite are at present doubtfully within the category of iron ores.

The famous iron mines of Middle Sweden at Dannemorra, Norrberg, Grängesberg, and Persberg occur under different geological conditions; they work lenticles or bands of ores in metamorphic rocks, of which some are altered sediments; and the view has therefore been held by de Launay and Vogt that the ores also are altered sediments.

That ores are formed by igneous segregation of sufficient size and purity to be of economic importance is a theory which rests on two chief cases—the nickel ores of Sudbury in Canada and the iron ores of Swedish Lapland.

2. *The Sudbury Nickel Ores.*—The nickel ores of Sudbury are the most important historically. They have been repeatedly claimed as of direct igneous origin by Bell (1891), von Foullon (1892), Vogt (1893), Barlow (1903), and by other geologists; and this view was advocated before the Association at the Johannesburg meeting by Professor Coleman. The theory was stoutly opposed by Posepny in 1893, and Professor Beck in 1901 described some of the brecciated ore, and showed that its metallic minerals are sharply separated from the barren rock. He held that such ore must have been formed, not only after the consolidation of the rock, but even after or during its subsequent metamorphism. The views of Posepny and Beck seem to have been established by additional microscopic study of the ores by C. W.

[1] F. Posepny, 'The Genesis of Ore Deposits,' *Trans. Amer. Inst. Min. Eng.*, 1893, p. 323.

[2] The Oxford Dictionary adopts a still more restricted definition; according to it an ore is 'a native mineral containing a precious or useful metal in such quantity and in such chemical combination as to make its extraction profitable.'

Dickson (1903). He has shown that the sulphides are separated from the barren rock by sharp boundaries, and without any indication of a passage between them; that the fragments of ore in the rock have short corners, whereas, had they grown in a molten magma, the angles would have been rounded, and the faces corroded. Most of the ore, moreover, occurs as a cement filling interspaces between broken fragments of barren rock and along planes of shearing. The Sudbury ores, therefore, appear to have been deposited from solution during or after the brecciation of the rocks in which they occur. and long after their first consolidation. If Dickson's facts be right, the Sudbury ores are necessarily aqueous and not igneous in origin.

3. *Scandinavian Iron Ores.*—The other important mining field of which the ores are claimed as of igneous origin is Swedish Lapland. Its ores are rich and the ore bodies colossal. One mine, Kirunavaara, yielded over one and a half million tons of ore in 1906, and according to a recent agreement with the Swedish Government the annual output of ore from that mine may be raised to three million tons by 1913.

The chief mining fields of Lapland, although situated to the north of the Arctic Circle, have long been known; for some of them contain veins of copper which were worked, for example, at Svappavaara in the seventeenth century. The iron ores, however, could not be used until a railway had been laid through the swamps of Lapland to carry the ores cheaply to the coast. In 1862 an ill-fated English company began a railway to the Gellivara mines, and thirty years later this was completed across Scandinavia, from the head of the Gulf of Bothnia at Lulea to an ice-free port at Narvik, on the Norwegian coast.

This railway, the most northern in the world, passes the two great mining fields of Gellivara and Kiruna. The mining field of Kiruna is the larger and at present of the greater geological interest, as its structure is simpler and its rocks less altered.

The ore body at Kiruna outcrops along the crest of a ridge two miles long, and it is continued beneath Lake Luossajarvi to the smaller but still immense ore body of Luossavaara. At Kiruna the ore rises to the height of 816 feet above the surface of the lake, and it varies in thickness from 30 to 500 feet, with an average thickness of about 230 feet. According to the report by Professor Walfrid Petersson,[1] submitted this year to the Swedish Parliament, Kirunavaara contains 200 million tons of ore above lake-level, and Luossavaara another 22½ million tons. The ore is high-grade. According to Lundbohm 60 per cent. of the trial pits showed a yield varying from 67 to 71 per cent. of iron, and 21 per cent. of them showed a yield of from 60 to 67 per cent. of iron. The average of nineteen analyses published in Professor Petersson's recent report gives the contents of iron as 64·15 per cent. Unlike the Taberg and Routivaara ores, the percentage of titanium is very low; thus in nineteen analyses given by Petersson the average of titanic acid is only 0·23 per cent., and it varies in the specimens from 0·04 to 0·8 per cent.

The ore lies between two series of acid rocks, which have been very differently interpreted, but will no doubt be fully explained by the researches now in progress under the direction of Mr. Lundbohm. The rocks were first called halleflinta, as by Fredholm, and regarded as of sedimentary origin. They are now accepted as an igneous series, associated with some conglomerates, slates, and quartzites. The ore body itself is bounded on both sides by porphyrites, of which that on the lower or western side is more basic than that overlying the ore to the east. The basic western porphyrite is in contact with a soda-augite syenite of which the relations are still uncertain. Interbedded with the overlying eastern porphyrite are rocks that appear to be volcanic tuffs, and both in the tuffs and in the upper porphyrite are fragments of the Kiruna ore.

Three main theories of the genesis of the Kiruna ores have been proposed. Their sedimentary origin was urged on the ground that they occur regularly interstratified in a series of altered sediments, and that the ores, therefore, are also sedimentary. This view may be promptly dismissed, since the adjacent rocks are igneous.

[1] *Bihang till Rikd. Prot.*, 1907, 1 Saml., 1 Afd., 84 Häft, No. 107, pp. 213, 217.

The second theory has been advanced independently by Professor de Launay and Dr. Helge Bäckström: according to them the porphyrites above and below the iron ores are lava flows, and the ore was a superficial formation deposited in an interval between the volcanic eruptions. According to de Launay the iron was raised to the surface as emanations of iron chloride and iron sulphide; the iron was deposited as oxide, and most of it subsequently reduced to magnetite during the metamorphism of the district.

The third theory—that the ores are of direct igneous origin—has been maintained by Löfstrand, Högbom, and Stutzer; according to them the ores are segregations of magnetite from the acid igneous rocks in which they occur. The segregation theory has been opposed, amongst others, by de Launay and Vogt. Thus, de Launay maintains that the segregation would have been impossible in such fluid lavas as the Kiruna porphyrites, and is improbable, since there is no transition between the ore and the barren rock.

The segregation theory has serious difficulties, and is faced by several obvious improbabilities. The ore occurs as a band nearly forty times as long as it is broad. It has the aspect, therefore, of a bed or a lode. The ore has not the granular, crystalline structure of an igneous rock like the hyperite of Taberg, but the aspect of a material deposited from solution or formed metasomatically. It is almost free from titanium, the undesirable constituent so abundant in the ores of Taberg and Routivaara.

The igneous theory cannot, however, be lightly dismissed, as it is supported by the high authority of Professor Högbom, and therefore demands careful consideration.

It has been advanced in two main forms, the one considering the ore to have been deposited at the time when the igneous rocks were consolidating, the other considering it was deposited at a later period. According to Professor Högbom, the ore was syngenetic, being a true magmatic segregation from a syenite. But, according to Dr. Stutzer (1906), the segregation was later than the consolidation of the syenite. He describes the lode as an intrusive banded dyke, of which the chief constituents are magnetite and apatite; and the injection of this dyke pneumatolytically affected the rocks beside it, producing an intermediate zone, impregnated with ore, which he compares to contact deposits.[1]

In spite of the high authority of Professor Högbom, I am bound to confess that the Kiruna ores do not impress me as of igneous formation. Their bed-like form, microscopic structure, and poverty in titanium are features in which they differ from those admittedly due to direct magmatic segregation. The microscopic sections that I have examined suggest that both the magnetite and apatite were deposited from solution and later than the consolidation of the underlying porphyrite, which the ore in part replaces. An examination of the field evidence supports the conclusions of de Launay and Bäckström as to the ore being a bedded deposit overlying a lava flow, but enlarged by secondary deposition.

V. *Future Supply of Iron Ores.*

This conclusion is perhaps economically disappointing. The possible existence of such vast segregations of iron in the acid igneous rocks has an important economic bearing. There is only too good reason to fear that the chief iron ores are comparatively limited in depth; for most of them have been formed by water containing oxygen and carbonic acid in solution, which has percolated downward from the surface. Ores thus formed are therefore restricted to the comparatively

[1] In a later paper, of which only a short abstract has been issued, Dr. Stutzer, however, explains that 'the intrusion of the ore dyke was at relatively the same time as the formation of the syenite, and that the ores were formed by magmatic separations *in situ*, or as peregrinating magmatic separations (magmatic veins and bedded streams).' He adds that 'pneumatolysis plays no inconsiderable rôle in the formation of these veins.' Dr. Stutzer's position may be summarised as regarding the ores as collected by segregation, but deposited in their present position by eruptive after-actions.

limited depths to which water can carry down these gases. On the theory, however, that these ores are primary segregations from deep-seated igneous rocks there need be no limit to their depth. They would rather tend to increase in size downward, while maintaining, or even improving, in the richness of their metallic contents. For these bodies may be regarded as fragments of the metallic barysphere which have broken away from it and revolve around it like satellites floating in the rocky crust. On this conception these ore bodies would be of as great interest to the student of the earth's structure, as their existence would be reassuring to the ironmaster, haunted as he is by constant predictions of an iron famine at no distant date. It is no doubt true that many of the richest, most accessible, most cheaply mined, and most easily smelted iron ores have been exhausted. The black-band ironstone and the clay iron ores of the coalfields, which gave the British iron industry its early supremacy, now yield but a small proportion of the ores smelted in our furnaces. The Mesozoic beds of the English Midlands and of Yorkshire still supply large quantities of ore. Nevertheless the British iron industry is becoming increasingly dependent on foreign ores. So it would be pleasant to find that the Scandinavian iron mines are not subject to the usual limits in depth. I fear the typical iron deposits of Middle Sweden and of Gellivara will follow the general rule; but Kiruna may be an exception, and its ores may continue far downward along the surface of its sheet of porphyrite. The uncertainty in this case lies in the extent of the subsequent enrichment and enlargement of the bed; if most of the ore is due to secondary deposition, then it may be restricted to the comparatively shallow depths at which this process can act; and though that limit will be of no practical effect for a century or more to come, the ore deposit may be shallow as compared with some gold-quartz lodes.

The geological evidence may convince us that all the economically important iron ores are limited to shallower depths than some lodes of gold, copper, and tin; but this conclusion shall not enroll me among the pessimists as to the future of the iron supply. Twenty years ago a paper on the gold supplies of the world was read to the Association at the request of the Section of Economics. About the time that the report was issued, there were sixty-eight mining companies with a nominal capital of 73,000,000*l.* at work upon the Rand. Nevertheless, the author, accepting the view that 'the future of South African gold-mining depends upon quartz veins,' concluded: 'There is as yet no evidence that the yield will be sufficient in amount to materially influence the world's production. As regards India, the prospect is still less hopeful.'

That quotation may be excused, as it is not only a warning of the danger of negative predictions, but of the unfortunate consequences that happen when geologists are unduly influenced in geological questions by the opinions of those who are not geologists. In economic Geology, as in theoretical Geology, we should have greater confidence in the value of geological evidence. Negative predictions are especially rash in regard to iron, it being the most abundant and widely distributed of all the metals. The geologist who knows the amount of iron in most basic rocks finds it difficult to realise the possibility of an iron famine; he can hardly picture to himself some future ironmaster complaining of 'iron, iron everywhere, and not a ton to smelt.' There are reserves of low grade and refractory materials which the fastidious ironmaster cannot now use, since competition restricts him to ores of exceptional richness and purity. When the latter fail, an unlimited quantity could be made available by concentration processes. The vast quantities of iron ores suitable for present methods of smelting in Australia, Africa, and India show that the practical question is that of supplies to existing iron-working localities, and not of the universal failure of iron ores.

VI. *Mining Geology and Education.*

The genesis of ores and the extent of future ore supplies are intimately connected questions, and the recognition of this fact has led to the remarkable growth of interest in economic Geology. This wider appreciation of the practical value of

academic Geology should, I venture to urge, be recognised among teachers by giving a more honoured place to economic Geology.

It was inevitable that until the principles of Geology had been firmly established, the detailed study of their application should have been postponed. Now, however, last century's work on academic Geology enables the dificult problems connected with the genesis of metalliferous ores to be investigated with illuminating, and practically useful results.

British interest in mining education has therefore been revived. Its history has been sadly fitful. Lyell,[1] in 1832, deplored the superiority of the Continent in this respect, as 'the art of mining has long been taught in France, Germany, and Hungary in scientific institutions established for that purpose,' whereas, he continues (quoting from the prospectus of a School of Mines in Cornwall, issued in 1825) 'our miners have been left to themselves, almost without the assistance of scientific works in the English language, and without any "School of Mines," to blunder their own way into a certain degree of practical skill. The inconvenience of this want of system in a country where so much capital is expended, and often wasted, in mining adventures, has been well exposed by an eminent practical miner.'

Though the chief British School of Mines made a late start, the brilliant originality of its professors soon carried it into the front rank; but in an evil day for the Mining School it was united with a Normal School for the Training of Teachers, now the Royal College of Science, and that school by its great success overwhelmed its older ally. Those interested in economic Geology therefore welcome the recent decision to separate the technical from the educational and other courses, while leaving the Schools of Mines and Science sufficiently connected for successful co-operation. This policy should give such opportunities for the teaching of mining research that we may not always have to confess, as at present, that British contributions to mining Geology do not rank as high as those made to other branches of our science.

Regrets are sometimes expressed, and perhaps still more often felt, at the tendency in scientific teaching to become more technical; but I, for one, do not fear evil from any such change. It is possible that the educational conflict of the future will be between academic science and technical science, on grounds in some respects analogous to those between classics and science during the last century. The advocates of the educational value of technical science are not inspired by mere impatience with the apparently useless, for they accept the principle that the essence of education is method, not matter. Therefore, they claim that the methods and principles of science can be better taught by subjects which are being used on a large scale in modern industries than by subjects of which the interest is still purely theoretical. Those who fear that academic science will be neglected if technical science be used in education may be encouraged by the brilliant revival of classical research since classics lost its educational monopoly. Academic science is even less likely to be neglected. It will always have its fascination for those intellectual hermits—shall I not say those saints of science?—who prefer to work for love of knowledge, free from the worrying intrusion of the mixed problems and fickle conditions of the industrial world; and the greater the progress of applied science the more urgent will be its demands for help from pure science, and, as a necessary consequence, the wider will be the appreciation and the more generous the endowment of scientific research.

Technical education must be as rigorous as that in academic education, and its connection with the fundamental principles must be as intimate. When so taught, economic problems provide at least as good a mental training as those branches of science which are purely theoretical. If the new Imperial College of Science and Technology carry on the mission for which the Geological Society was founded a century ago. If it inspire its students to have their delight in using past discoveries on the open surface of the earth, so that they may penetrate to what is within, then they will gain that sure knowledge of the formation and distribution of ores, which is of ever-growing national importance.

[1] C. Lyell, *Principles of Geology*, vol. i., ed. 2 (1832), p. 63.

The following Papers were then read:—

1. *Notes on the Geology of Leicestershire. By* C. Fox Strangways, *F.G.S.*

The chief features of the district were briefly described, with a general account of the formations that are exposed throughout the county. These are comprised in the following main divisions in descending order: Recent and Pleistocene; Jurassic; Triassic; Permian; Carboniferous; and Pre-Cambrian. The first of these includes the river deposits and glacial beds. The Jurassic rocks comprise only the two lower subdivisions of the Lincolnshire Limestone and the Northampton Sand, together with the Lias. The Trias occurs in the usual two divisions of Keuper and Bunter. The Permian consists of breccia and marls, the age of which is to some extent doubtful. The Carboniferous is well exemplified in the three subdivisions of Coal-measures, Millstone Grit, and Limestone; but the lower beds are not of the importance they attain elsewhere. The Pre-Cambrian rocks are divisible into three main groups, as shown by Professor W. W. Watts—the Brand Series, the Maplewell Series, and the Blackbrook Series. Special attention was directed to the more important exposures of these rocks, and to the principal points in the local geology that are obscure and require further elucidation.

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2. *The Geology of Charnwood Forest. By* Professor W. W. Watts, *F.R.S.*

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3. *The Felsitic Agglomerate of Charnwood Forest.*
By F. W. Bennett, *M.D., B.Sc.*

The rocks lying between the Beacon Series and the Blackbrook formation comprise a greater variety than has been hitherto recognised. Three main beds can be distinguished, which may be called the coarse, white, and pink grits. The pink grit, which is the uppermost bed, is the one to which almost exclusively the name of 'Felsitic Agglomerate' has been hitherto given.

Careful examination of the rocks in the Buck Hills has now conclusively proved that they belong to the Felsitic Series

The rocks in the north-west of the forest have always given rise to much difficulty. It is possible to trace the Felsitic Agglomerate as a distinct series of rocks in Timberwood Hill. The ground in this part of the forest has been extremely faulted, and a good example of this occurs in Collier Hill.

To the north of the monastery, rocks have now been traced which evidently lie on the horizon of the Felsitic Series. They differ in some ways from the ordinary agglomerate type, especially as regards their texture, which becomes highly crystalline. It is found that these Felsitic rocks have been intruded into by igneous flows, both near the Cademan area and also in Bardon Hill; and it is probably due to this cause that the texture of the rock has been so much altered.

The position of these beds in relation to the Bomb rocks makes it probable that they correspond to the Felsitic Series, and this correlation is confirmed by comparison of some of the more recently discovered types with those of the ordinary Felsitic Agglomerate rocks.

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4. *The North-West District of Charnwood Forest.*
By Bernard Stracey, *M.B., F.G.S.*

As the north-west of Charnwood Forest is approached the rocks become more altered, the faulting is greater, and igneous rocks are met with. The vent which ejected the rocks of the forest seems to lie in this direction.

Bardon Hill.—The centre and part of the north flank are composed of rock resembling an igneous rock; evidence is given to show that this rock differs from the agglomerates found in the north-west area, with which it has hitherto

been correlated. Certain rocks between the Bardon rock and the Peldar porphyroid seem to bear some relation to the Felsitic Agglomerate.

Birchill Plantation.—Recent research in this exposure has shown the identity of the rock with that found at Bardon Hill. On the north side rocks belonging to the Felsitic Agglomerate Series have also been found.

Peldar Tor.—The porphyroid exposed in the large quarries contains inclusions of other rocks, which have been generally considered as segregation masses. An undoubted dyke in the middle of Peldar Tor has been exposed.

Ratchet Hill.—An exposure in this hill shows the presence of rocks on the Felsitic Agglomerate horizon. At the north-west end a porphyroid occurs which seems to be identical with the porphyroid at Cadman Wood.

Swannymote and Trilobate.—Rock belonging to the Felsitic Agglomerate Series runs between these two places, it has been much altered, and has not hitherto been recognised as belonging to the Felsitic Agglomerate.

FRIDAY, AUGUST 2.

The following Papers and Report were read :—

1. *Some Desert Features.*[1] *By* H. T. Ferrar, *M.A.*, *F.G.S.*

Contrast between the deserts on either side of the Nile.

The *Western Desert,* sometimes known as the Libyan Desert, presents all the features which one would expect to find in a region of deficient rainfall. There are broad featureless plains with no very definite drainage systems; there are long lines of sand-dunes stretching for tens of miles across the country; there are centripetal basins, and there are monadknocks or inselbergen, and an almost entire absence of vegetation.

The *Eastern Desert,* or the Etbai, on the other hand, displays an integrated drainage system; sand-dunes are conspicuous by their absence; vegetation is not scarce; and comparatively high mountains form a backbone to the country. These mountains are a true chain and form the water-parting between the Nile and the Red Sea. This water-parting is very much nearer the east coast, and, as in South Africa, so here we have the shorter and steeper eastward draining wadis beheading the longer westward drainages. The highest peaks usually consist of granite, which is sometimes foliated, and these high peaks, which rise majestically above the denuded schistose rocks, are not always on the actual watershed. Forms of rock and mountain sculptured by sandblast are not obvious, for the rain which occasionally falls destroys these and produces typical water-graded slopes.

The western desert surfaces consist of a thin veneer of waste, except where monadknocks or the escarpments of the oases display solid rock. This veneer of waste is protected, as in the Antarctic regions, by a layer of pebbles, which prevents the wind transporting the lighter material and prevents the rain-water from flowing in definite channels.

The eastern, or Etbai, desert shows bare hillsides, and the steep cliffs which form the wadi-walls are quite free from débris. The wadis or dry watercourses are at present being aggraded, and it is only in the wadi-beds that one finds the alluvium. This alluvium of boulders and rock-débris is usually from 5 to 50 ft. in depth, and may be described as a torrential deposit. The only sorting of materials that is obvious in this region is that sorting due to water-action, where the volume of water and the slope of the ground are the determining factors.

Sorting of fine material from the coarse is not as common as one would expect. A high wind (Beaufort scale, force 8) will only move pebbles and grit less than 5 mm. in diameter, so that a succession of winds of unprecedented force would be necessary to produce 'pebble beds.' The pebbles of the gravels on the western plateau, near Wadi Natrum, are all rounded and water-worn, and form a heavy

[1] By permission of the Director-General, Survey Department, Egypt.

mantle over the land which prevents the wind from picking up the lighter material from below, which they protect. It is only those stones on the surface that are wind-etched or show the faceted form. These gravels were deposited during the pluvial period, immediately preceding the present arid one, and therefore it would seem that the only reliable test to prove that a deposit was a desert formation would be to find in it tetrahedral and wind-etched stones.

2. *Fifth Report on the Fauna and Flora of the Trias of the British Isles* —See Reports, p. 298.

3. *On the Structure of the Mandible in a South African Labyrinthodont.* *By* Professor H. G. Seeley, *F.R.S.*

The specimen was found by Mr. Alfred Brown at Aliwal North and presented to the British Museum. It is a segment from a ramus indicating a skull about 2 feet long, and at the transverse fractures shows the Meckel cartilage cavity and the bones around it. There are two external bones—the dentary, which carries large teeth in shallow sockets, and parallel to it is the infra-dentary. This element, found in certain fish, has not been observed before in Labyrinthodonts. On the inner side of the Meckel cartilage are two bones: one of these is seen externally on the base of the jaw, and regarded as the angular bone. Above it is the surangular bone, which carries a row of teeth rather smaller than those in the dentary bone. On the inner side of the jaw is the splenial bone, which hides the suture between the angular and surangular bones. The teeth are solid and have a relatively simple labyrinthic structure. The fragment shows that with the coronoid and articular bones the mandible may include seven elements on each side or more.

4. *The Origin of the Upper Keuper of Leicestershire.* *By* T. O. Bosworth, *B.A.*, *F.G.S.*

The Condition of the Rocks beneath the Keuper.—The Charnian igneous rocks beneath the Keuper are comparatively fresh right up to their surfaces, but where the marl has been denuded and the rocks are exposed to the present climate they are decomposed.

The Surface Features of the Rocks beneath the Keuper.—Smoothed, fretted, and curiously carved surfaces are seen at Mount Sorrel,[1] Croft, Sapcote, Groby, &c., and usually wherever the marl rests on igneous rocks. They are often pitted and sometimes highly polished (*e.g.*, at Narborough). But where the rocks are cleaved or broken, as at Swithland and Bardon, the floor beneath the Keuper is rough and craggy.

The Nature of the Deposits.—Everywhere the beds dip in the direction of the surface slopes on which they lie, and the amount of dip depends upon the steepness of the slope. Catenary bedding is seen at Croft and Groby. Near the rocks the marl contains grit and stones, and there is generally a breccia at the base. The stones are of varied sizes, sometimes worn and sometimes very angular. They are in a remarkably fresh condition.

Both stones and grit are derived entirely from the particular rocks which the beds containing them surround. In these beds there is often a small amount of quartz sand, sometimes apparently wind-worn. It yields the same heavy minerals as the 'Upper Keuper Sandstone.'

In many cases—*e.g.*, around the S. Leicestershire igneous rocks—this sand cannot be of local origin.

At Croft some of the Upper Keuper Sandstone consists of almost spherical grains, and appears to be a desert sand.

[1] Prof. Watts, *Geographical Journal*, June 1903.

Near Leicester the sandstone is uniformly false-bedded from the south-west, and *Estheria* and fish-scales occur upon the false-bedding planes. Heavy mineral separations have been prepared from a large number of localities throughout the country. The mineral grains are generally very much worn. The most plentiful are garnet, magnetite, zircon, tourmaline, and rutile.

In the normal Keuper Marl, bands showing false bedding, ripple marks, and salt pseudomorphs are generally common, but such evidence of sub-aqueous deposition as there is points rather to the existence of occasional streams and salt pools than to the deep waters of one great Keuper lake.

It is inferred that the Upper Keuper is a desert accumulation.

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5. *The Relation of the Keuper Marls to the Pre-Cambrian Rocks at Bardon Hill. By* W. KEAY *and* MARTIN GIMSON.

Bardon Hill is situated in the Charnwood Forest area, about ten miles north-west from Leicester. The hill rises to an elevation of 912 feet, and is higher than any of the land intervening between this point and the German Ocean.

The hill consists of Keuper marls resting unconformably upon Pre-Cambrian rocks, the latter protruding about 100 feet through the marls.

The object of this paper was: (1) To remark upon the unusual elevation of the Keuper marls; (2) To consider the probability of the entire submergence of the hill during the Triassic period.

1. *Elevation.*—Acting upon a statement of Professor Phillips that 'the Triassic system offers the remarkable fact of never rising to elevations much above 800 feet,' the authors by personal inspection, where possible, and by the aid of ordnance levels, failed to discover any point on the Trias in England reaching a greater height than 800 feet except at Bardon Hill. Here, 'skerry' bands in the Keuper marl may be seen at a height of 810 feet, and the marl may be traced in the fissures of the Cambrian rocks to a height of 880 feet. Hence the conclusion that the Keuper marls at Bardon reach an elevation at least as high, and possibly higher than at any other point in the same strata in England.

2. *Submergence.*—The probability of Bardon Hill (912 feet), and therefore the whole Charnwood area, being entirely submerged during Triassic times presents itself as a problem.

The authors found at 810 feet two distinct 'skerry' bands resting upon, and overlain by, Keuper marl. In the Siberia Quarry the marl is found filling in two joints which rise nearly vertically a height of 80 feet. This 'filling' may be traced in the joints to a level of 880 feet, or 32 feet below the summit of the hill. There is no evidence suggesting the sudden termination of the marl at this level, but further tracing was prevented by vegetation. It is obvious that the marl must have been deposited from an elevation higher than 880 feet.

Further evidence in support of submergence was offered as follows: The general dip of the marls in this district is from 1° to 3° S.E. Allowing an inclination of 1° only, or 90 feet per mile from a point at the junction with the Rhætics near Leicester, this would give (on the assumption that this inclination originally extended to Bardon) a covering of over 200 feet of marl above the present hill.

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6. *On a Peculiarity in the Mineralogical Constitution of the Keuper Marl. By* C. GILBERT CULLIS, *D.Sc., F.G.S.*

It has often been proved that the Keuper marl is, in places, markedly calcareous; but little has hitherto been done to show in what mineralogical form the calcareous matter exists in such cases. To determine this an investigation was made, and the results obtained, together with a suggestion as to their significance, are here recorded.

Most of the specimens examined were taken from the well-known cliff-section at Westbury-on-Severn, about eight miles S.W. of Gloucester. Treatment with

acid shows that the marl from this locality is highly calcareous; and thin sections of it under the microscope reveal the condition in which some, if not all, of the calcareous matter exists. Scattered through the matrix of the rock there occur great numbers of minute crystals of rhombohedral carbonates. Experiments made by the author and Mr. Russell F. Gwinnell upon some of these crystals isolated from the rock proved that they are not calcite. Further tests by micro-chemical methods demonstrated the presence in them of both calcium and magnesium, and pointed to their being *dolomite* To test this identification a washed residue of the marl, containing practically nothing but quartz grains and the crystals in question, was submitted to Mr. G. S. Blake, of the Imperial Institute, for analysis, with the result that the identification was confirmed.

These dolomite crystals, which have the form of the fundamental rhombohedron, and are extraordinarily perfect, are always very minute, ranging in size from individuals just visible to the naked eye to others which can only be seen with high powers of the microscope. They occur in the red parts of the marl as well as in the green. They were also found in specimens of the marl from other localities in the district, extending as far north as Worcester, and doubtless occur in it outside the area already investigated. Moreover, they occur sometimes in great profusion; indeed, from analyses by Dr. Moody[1] of samples from the Wainlode exposure, it may be inferred that they sometimes make up as much as 25 per cent. of the mass.

Very similar variegated marls occur in the Gloucester area, at the base of the Old Red sandstone, and samples of these were compared with the Keuper marl. It is an interesting and probably significant fact, in connection with the conditions of formation of these two deposits, that no dolomite crystals were found in these Devonian marls.

It seems likely that the presence of these crystals in the Keuper marl is an expression of the special conditions which prevailed during its accumulation; and the author, though aware of other possible modes of origin, is inclined to the view that they were *precipitated from solution* from the waters of an inland sea or a lake at the same time as the remainder of the marl was being *deposited from suspension*. This view is supported by the fact that other substances thrown down from solution during the desiccation of large sheets of water, such as gypsum and rock salt, are familiar constituents of the marl of other and not distant localities.

It has been suggested that the Keuper marl may represent an accumulation of wind-borne dust, a Triassic loess formation. But the presence of these dolomite crystals in it seems to the author to militate against this view and to point to the conclusion that such portions of it, at any rate, as contain the crystals were laid down under water.

The existence of these dolomite crystals is interesting from one other point of view, inasmuch as it affords a possible explanation of the fact that in many localities where the New Red marls rest directly upon limestones these latter are found to be partly or wholly dolomitised. Waters obtained from the Keuper marl at Blaisdon, near Gloucester, have recently been shown to be so highly magnesian as to be unfit for drinking; the magnesium has presumably been acquired by the solution of the minute dolomite crystals. Such waters by percolation through underlying limestones might very well effect the dolomitisation so often observed in them.

MONDAY, AUGUST 5.

The following Papers and Reports were read:—

1. *Iron Ore Supplies.*

(i) *By* Bennett H. Brough, *F.G.S.*

Of all the problems with which the practical geologist has to deal, none is of greater importance at the present time than the discovery of fresh sources of iron

[1] *Quar. Journ. Geol. Soc.*, vol. lxi. 1905, p. 431.

ore supply. Every inhabitant of the United Kingdom, of the United States, and of Germany requires annually about a quarter of a ton of the iron of which the world last year produced 60,000,000 tons, the result of the smelting of over 120,000,000 tons of ore. Year by year the production and consumption are increasing, and many of the deposits of the richer ores are showing signs of depletion. The question of ascertaining how the demand for the vast supplies of iron ore that will in the future be needed will be met calls, therefore, for very serious consideration; and a few statistical notes may be useful as a contribution to a discussion of the subject.

During the past half-century the development of the iron industry has been remarkable. In 1854 Mr. J. K. Blackwell showed that the world's production of pig-iron did not exceed 6,000,000 tons, of which the United Kingdom produced 50 per cent., France and the United States each 12½ per cent., and Germany 6·6 per cent. In 1905 the world's production had attained the enormous total of 56,000,000 tons, of which the United States produced 42·7 per cent., Germany and Luxemburg 20 per cent., the United Kingdom 17·6 per cent., and France 5·5 per cent.

In Great Britain the principal iron-ore producing districts are Cleveland, in North Yorkshire, which in 1905 yielded 41·0 per cent. of the total output of the kingdom; Lincolnshire (14·8 per cent.), Northamptonshire (13·9 per cent.), and Leicestershire (4·7 per cent.), together yielding 33·4 per cent. of the total output; Cumberland (8·6 per cent.) and North Lancashire (2·7 per cent.), Staffordshire (6 1 per cent.) and Scotland (5·7 per cent.). The Cleveland iron ore occurs in a 10-foot bed in the Middle Lias, and contains about 30 per cent. of iron. It is worked by underground mining. In Lincolnshire, Northamptonshire, and Leicestershire the brown iron-ore beds form part of the Inferior Oolite, and contain about 33 per cent. of iron, the workings being mostly opencast. In Cumberland and North Lancashire the red hæmatite occurs in irregular masses in carboniferous limestone. It contains more than 50 per cent. of iron, and is worked by underground mining. The ironstone in Staffordshire and in Scotland is mostly obtained from mines that also produce coal.

Such, in brief, are the home deposits from which the British supply of 14,590,703 tons of iron ore, valued at 3,482,184*l.*, was obtained in 1905. Even that enormous output did not meet the consumption, and 7,344,786 tons were imported. Of that amount 78·5 per cent. was brought from Spain, 5·4 per cent. from Norway, 4·2 per cent. from Greece, 4 per cent. from Algeria, 2·6 per cent. from France, 2·6 per cent. from Sweden, 1·5 per cent. from Russia, and smaller quantities from Turkey, Germany, islands in the Pacific, Belgium, Newfoundland, India, Australia, Italy (Elba), Persia, Portugal, and other countries. In fact, the world is being ransacked for fresh iron-ore fields to supply ores for the British blast-furnaces. The port at which most of the ore was delivered was Middlesbrough (1,789,639 tons), then followed Glasgow with 1,042,179 tons, and then Cardiff with 875,462 tons.

While it is probable that the British iron-ore fields will be exhausted in a century or two, the outlook in other countries is similar. This is borne out by data relative to the available iron-ore supplies of the world which have been collected by Torneböhm for the Swedish Parliament, and, although largely conjectural, these figures are of great interest.

In the United States the iron-ore production in 1905 exceeded 42½ million tons, the highest output ever recorded, the ore containing more iron than the ores raised in Germany, in the United Kingdom, and in Spain combined. The bulk of the production was obtained in the Lake Superior region, where the five iron-ore belts, or ranges (Marquette, Menominee, Gogebic, Vermilion, and Mesaba), beds of pre-Silurian Age, have furnished since the beginning of regular mining over 300,000,000 tons of iron ore. The average percentage of iron in the ore is 55, the 60 per cent. ores produced ten years ago having been exhausted by wasteful mining methods. The amount of ore still available in the United States is estimated by Törnebohm at 1,100,000,000 tons.

In Germany and Luxemburg two-thirds of the iron ore raised (23½ million

tons in 1905) is derived from the so-called minette beds of Jurassic brown iron ore. The seams yield on an average 36 per cent. of iron and 1·7 per cent. of phosphoric acid. Owing to the high percentage of phosphorus the ore was of little value until 1879, when the basic method of making steel was brought into practical use by Thomas and Gilchrist. The amount of ore still available in Germany is estimated at 2,200,000,000 tons.

In Spain the chief deposits are near Bilbao; the ores, which are of great purity, occurring in beds of Cretaceous age. Up to the present time the Bilbao district has yielded about 115,000,000 tons of ore, and for many years pessimistic estimates have been made of the quantity of ore remaining. Twenty years ago it was thought that by the year 1900 there would be no ore left. Nevertheless, in that year Bilbao exported 5,000,000 tons of ore, and Don Julio de Lazurtegui, the most competent authority, estimated that there were still over 57,000,000 tons left. The richest red hæmatite ores are, it is true, now exhausted, and brown hæmatites and spathic ores have taken their place, with the result that more attention has to be paid to calcination and to the washing of ores to enable them to satisfy market requirements. Törnebohm's estimate of the quantity of ore still available in Spain is 500,000,000 tons.

In Sweden deposits of magnetite of great purity occurring in gneiss supply material for the charcoal blast-furnaces, and ores rich in phosphorus are mined for export at Grängesberg, in Central Sweden, and within the Arctic Circle at Gellivare, Kirunavaara, and Luossavara, where there are ample supplies to meet the increased demand that is likely to arise. These deposits have been described in great detail by Dr. Stutzer in a paper submitted at the last meeting of the Iron and Steel Institute. The export of iron ore from Sweden in 1905 amounted to 3½ million tons. In Northern Norway important discoveries of similar iron-ore deposits have of late been made. The amount of ore still available in Sweden is estimated at 1,200,000,000 tons.

In France the most important deposits are the beds of Oolitic iron ore in the department of the Meurthe-et-Moselle; and in Russia the greater portion of the iron ore produced is obtained from the Ural region, where, on the western side, the ores are chiefly limonite and spathic ores of a stratified character, and, on the east, masses of magnetite associated with igneous rocks. The amount of ore available in France is estimated at 1,500,000,000 tons, and in Russia at the same amount. The available resources of other countries are estimated by Törnebohm at 1,200,000,000 tons. Including 1,000,000,000 tons for Great Br.tain, he estimates the known available resources of the world at 10,000,000,000 tons.

The outlook for the British industry is not altogether a depressing one; for, whilst the rich ores of Bilbao and Elba are becoming scarce, there are still vast quantities of ore available in the north of Scandinavia, in the south of Spain, in Algeria, Canada, Cuba, Brazil, Venezuela, Chili, India, China (notably in the Shansi district), Australia, and South Africa. The high cost of carriage is, of course, an important factor; but the great economies which have, and will be, effected in transport will reduce this item. The future of the home demand is likely to be affected by the development of the basic open-hearth process of steel-making which enables phosphoric ores to be utilised. In the course of time such phosphoric ores will doubtless occupy a very prominent place in the manufacture of high-class steel. The development of magnetic concentration and of the briquetting of pulverulent ores for furnace use will render possible greater utilisation of poorer ores, while the development of the electric furnace will doubtless render it possible to utilise black sands and other titaniferous iron ores which, although met with in abundance, cannot at present be treated profitably in the blast-furnace. There need therefore be no immediate anxiety regarding the supply of the more impure iron ores, the application of which cannot fail rapidly to increase.

(ii) *The Iron-ore Supply of the Scandinavian Peninsula.* *By* Hj. Sjögren.—See Reports, p. 332.

2. *The Distribution of Radium in the Rocks of the Simplon Tunnel. By* Professor J. Joly, *Sc.D., F.R.S.*

The principal classes of material which enter into the composition of the massif of the Simplon are: (*a*) The Jura-Trias sediments, lithologically often much alike and much interfolded; (*b*) the Palæozoic crystalline schists; and (*c*) the gneiss of Monte Leone and the Antigorio gneiss, both stated to be of Archæan age. These rocks throughout contain radium, and for the most part in quantities much above what hitherto has been ascribed to sedimentary or igneous rocks.

Some thirty-six typical samples, taken from various points in the tunnel, have been examined. The poorest in radium are certain anhydrite rocks. Certain amphibolite schists go very high. The Antigorio gneiss rises from $10{\cdot}5 \times 10^{-12}$ and $8{\cdot}0 \times 10^{-12}$ grams radium per gram of rock at the Italian entrance to $23{\cdot}7 \times 10^{-12}$ at 4000 metres inwards. Some of the Archæan gneisses yielded very high results.

Such quantities of radium if generally distributed throughout the rocks of the massif would be sufficient to disturb any forecast of the temperature which under normal conditions would be encountered at the level of the tunnel. It is suggested that the radium was in fact the source of the discrepancy between the predicted and the observed rock temperatures.

As it is improbable that these results are unique and apply only to this particular sedimentary accumulation and locality, they appear to point to hitherto unsuspected quantities of radium (and its parent elements) in the immediate surface materials of the earth. It seems impossible to avoid the conclusion that these elements were precipitated along with the sediments entering into the composition of the massif. The question then arises whether the accumulation of such quantities of radioactive elements may not enter as a factor in the events attending mountain-building. It can be shown that an area of sedimentation whereon has been accumulated some 10,000 metres of sediments, having a richness in radium comparable with the Simplon rocks, must necessarily become an area of greatly lessened crust-rigidity, and would hence become the probable site of crust-flexure under tangential compressive stress.

Further investigation will be required before such views can be generalised and the importance of radium as a source of instability of the earth's crust be determined. Apart from any speculations as to the influence of radium as the cause of an energetic substratum, the shifting of radium and its parent elements by denudation must be regarded as a convection of thermal energy, and this convection, if the quantities involved are sufficient, must, under the conditions referred to above and the unceasing action of denudation, become rhythmic in operation, and at the same time must result in shifting the areas of high temperature and crust-weakness from age to age as the site of sedimentary accumulation changes.

3. *On the Pisolitic Iron Ores of Wales. By* W. G. Fearnsides.

The first part of the paper discussed the occurrence of the well-known iron ores of Caernarfon and Merioneth, and showed that, though they have been taken by various writers as marking a well-constituted subdivision of the Tremadoc slates, they are really of the nature of fissure phenomena, and may occur at almost any horizon.

The various worked exposures seem always to agree in the following particulars:—

1. They are associated with the occurrence of large hypabyssal or minor plutonic intrusions of sill-like habit, and occur among stratified rocks along the limit of the sill's metamorphic area.

2. They occur in more or less lenticular masses, of no considerable lateral extent, often heaped together, and separated by crushed shale partings in a way which may suggest bedding, but often thinning out, yet maintaining a linear arrangement across considerable tracts of country.

3. Considerable lenticles of ore are always associated with dark-blue or black shales or slates, which, nearer to the igneous intrusion, have become bleached and spotted through the influence of that intrusion. On the side of the ore body nearest the intrusion the country rock is usually little disturbed, and lies evenly; but on the side remote from the intrusion the country rock is crossed and recrossed by planes of slickenslide, and is often intensely nodular.

The more important stratigraphical horizons which have developed pisolitic ore bodies in the North Welsh district are:—

(1) Lower Lingula Flags. Bettws Garmon.

Black shales which underlie the grey flaggy sandstones with Lingulella beds.

(2) Upper Lingula Flags. N. flank of Aran Mawddy.

Adjoining shales contain *Peltura scarabæoides.*

(3) Upper Arenig Shales. Moelwyn Bach; Milltirgerig Arenig; below Llyn y gader, Cader Idris.

Country rock contains abundant *Didymograptus bifidus.*

(4) Llandeilo Shales (Glenkiln facies). Tiddyn Diewm, Tremadoc.

Country rock contains graptolites of the *Didymograptus Murchisoni* and *Cœnograptus gracilis* zones.

The workings of Pistyll, near The Rivals, seem to belong to a horizon higher than any of these, and may be among the Hartfell Bala shales.

The second portion of the paper dealt with the probable petrological and chemical history of the iron ores.

Evidence was brought forward to show that the ore bodies have only been profitable near the present surface, and when smelted with wood charcoal. They are always very rich in pyrites or marcasite, which in certain specimens from the deep termination of an adit make up about 60 or 70 per cent. of the rock. The ores are always impure, and contain much crushed, streaky, or fibrous shale between the pisoles. Where freshest the pisoles of sulphides show only radial arrangement of the constituent fibres, but there may also be concentric structures which are masked by the opacity of the mineral. The radial fibres of the mineral sulphides usually grow out from or around quartz grains or other clastic fragments of country rock or of earlier-formed broken pisolitic grains. During oxidation the sulphide is attacked in stages from the outside and passes by obscure processes first to a colourless and soluble green pleochroic mineral, and afterwards to fibrous limonite and compact magnetite. It is the differential development of the various stages which gives the resultant pisoles of the profitable ore their well-marked concentric structure.

That all the pisolitic grains contained in the iron ores of North Wales have been formed as radial growths of iron sulphides is not yet clear; but the method of their geological occurrence will well accord with the hypothesis that they may be the concentration products of the non-carbonaceous colouring matters driven off by the heat of the intrusion from the black shales considered above.

An occurrence of perfectly fresh masses of radial pyrites at the limit of a 12–20 foot metamorphic aureole in the Llandeilo shale of Harper's Quarry, Builth, shows that such concentration does occur on a small scale, while the finding of considerable lenticles of iron pisolitic ore which are wholly pyrites, and have been concentrated during the turning of coal into anthracite in the Emlyn Mine, Llandeby, near Llandeilo, would seem to show that reformed pyrites does tend to take on a pisolitic habit.

4. *The Trilobite Fauna of the Shineton Shales.* *By* F. Raw, *B.Sc., F.G.S.*

The author passed in review the already known trilobites from the Shineton Shales and announced the occurrence of several new forms. For the material he

is mainly indebted to H.M. Geological Survey, to Dr. Groom, and to Dr. J. Frazer.

Taking first the forms described by Dr. Callaway, the suggestions of Brögger and Linarsson were confirmed as to the following species:—

Olenus triarthrus, Call.	which now stand as	*Parabolinella triarthrus*, Call., sp.
Conocoryphe monile, Salt.		*Euloma monile*, Call., sp.
Conophrys salopiensis, Call.		*Shumardia pusilla*, Sars., sp.
Platypeltis Croftii, Call.		*Symphysurus Croftii*, Call., sp.

The Shineton *Shumardia* just mentioned is identical with the Scandinavian species, while with *Symphysurus Croftii* Brögger's later described *S. incipiens* appears to be identical.

Of Dr. Callaway's other species: *Asaphellus Homphrayi*, Salt., the writer referred to the genus *Megalaspis*; and for *Olenus Salteri*, Call., with which *O. Mitchinsoni*, Thomas, is identical, he proposed the name *Leptoplastides Salteri*, n. sub-gen., Call., sp. (See next abstract.)

Lichapyge cuspidata, Call., based on an isolated tail, is completed, the writer believes, by a head and thorax collected by Mr. Rhodes for H.M. Geological Survey, and appears, as was inferred by Dr. Callaway from the tail, to be related both to *Paradoxides* and to *Lichas*.

Of new forms the fauna includes another *Agnostus*, *A. Callavei*, Raw, of which a description by the writer has already appeared. Besides the Oleni mentioned above, the writer wished to establish another, which he believes, has been confused—the head with *P. triarthrus* and the thorax with *Leptoplastides Salteri*. It is very close to, but distinct from, the *Triarthrus spinosus* of Billings. It approaches also very closely to the '*Peltura*' *punctata* of Misses Crossfield and Skeat, from which it only differs in the possession of spines on the cheeks and down the axis, and of this form it may well be the ancestor. This and the Shineton form, though bearing a superficial resemblance to the type species of *Triarthrus*, are yet quite isolated, and should perhaps constitute a new sub-genus. For the new form the writer proposes *Triarthrus shinetonensis*, n. sp.

Two new Asaphids have to be recorded: one is a small-eyed *Symphysurus*, for which the name *S. microphthalmus*, n. sp., is suggested; the other is a new genus which appears to connect *Niobe* and *Ogygia*, having the tail of the former, but spined pleuræ, approaching those of *O. Selwyni*, Salt. This was named *Desmus Cobboldi*, n. gen. and sp., and the genus will be found to include some other European forms.

A new and strange form occurs, characterised by long spines like wings on the fixed cheeks and a tail resembling that of *Dicellocephalus* (e.g., *D. pepinensis*), for which the name *Pterocephalus hemicycloura*, n. gen. and sp., is proposed.

A single tail represents *Dicellocephalina furca*, Salt., sp., of which it may be regarded as a variety, distinguished by its beautifully curved contour.

But what is in many ways the most interesting trilobite is a species of *Orometopus*, *O. elatifrons*, Ang., sp., of which the collections by Mr. Rhodes for H.M. Geological Survey and by Mr. Cobbold have furnished the entire form. Only the cranidium had hitherto been known, and this Brögger compared with *Arethusina* and *Cyphaspis*. But the characters of the complete form unmistakably place it in the Trinucleidæ, though it is possessed of normal eyes. Moreover, being both more generalised and more primitive than the previously known members of this family, it indicates that the Trinucleidæ have been derived by specialisation and atrophy of the eye from more normal and eyed ancestors. Such degeneration is already anticipated in *Orometopus*, the eye of which is very small, consisting apparently of only sixteen facets. By its many points of agreement also with *Harpes*, it points to a common origin for that family and the Trinucleidæ, the atrophy of the eyes being, however, developed independently in each family. Indirectly it indicates also that other blind forms, such as *Conocoryphe*, have been derived from normally eyed ancestors.

The complete list of trilobites from the Shineton Shales known to the writer thus stands as follows:—

Parabolinella triarthrus, Call., sp.
Leptoplastides Salteri, Call., sp.
Megalaspis Homphrayi, Salter, sp.
Symphysurus Croftii, Call., sp.
Agnostus dux, Call.
Euloma monile, Call., sp.
Shumardia pusilla, Sars., sp.
Lichapyge cuspidata, Call.
Orometopus elatifrons, Ang., sp.
Triarthrus shinetonensis, sp. nov.
Dicellocephalina furca, Salter, var.
Symphysurus microphthalmus, sp. nov.
Desmus Cobboldi, gen. and sp. nov.
Agnostus Callarei, Raw.
Pterocephalus hemicycloura, gen. and sp. nov.

All except the last have been obtained from the main fossiliferous horizon in Shineton brook, and a comparison with the latest and most complete list of the fauna of the *Ceratopyge* series of Scandinavia, given by Moberg 1906, indicates that this horizon falls within the *Shumardia* zone of that author, while the complete fauna of the shales indicate that they include also the *Bryograptus* and *Dictyomena* zones below.

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5. *The Development of* Olenus Salteri, *Call. By* F. Raw, *B.Sc., F.G.S.*

Among the specimens from Shineton collected by Mr. Rhodes for H.M. Geological Survey are some small slabs covered with minute individuals of *Olenus Salteri*, Call., so that the early stages of growth are well represented, and it has been possible to trace the development of this species from individuals with only two thoracic segments upwards.

The adult reaches a length apparently of 1½ or 2½ inches, but only two specimens indicate such sizes. The head closely resembles that of *Leptoplastus*, e.g., *L. stenotus*, Ang., the free cheeks bearing exactly similar spines. The eyes, however, are somewhat closer. The thorax, too, is very similar, having exactly the same shape of pleural ends, though the axis is much broader in proportion. The tail, however, is quite different from that genus, being broader than long, emarginate behind, and entire, as against triangular and toothed.

But as the form is traced back from the adult through younger and younger individuals considerable changes appear. The tail becomes toothed and pointed, and finally very spinose. The ends of the thoracic pleuræ become long backwardly directed spines. The glabella, sensibly smooth in the adult, becomes segmented and narrow, and furnished with prominent eye-lines. The cheek-spines take a more forward position, and two additional pairs of spines appear.

With a few less segments than the adult there is a definite *Leptoplastus* stage, while an earlier stage still, with seven segments, is very close to such an early *Parabolina*, as *P. acanthura*. These later stages of development can, the writer thinks, be taken as indicating the evolution of the form, and so as pointing out its systematic position. As to the latter we cannot refer it to any existing sub-genus of *Olenus*. Superficially it approaches nearest to *Cyclognathus costatus*, Brögger, from which the head differs in bearing spines, and in having a frontal limb, characters which again connect it with *Leptoplastus*. Indeed it can hardly have been derived from any other known genus. From comparisons of adult *Oleni*, and their succession, and from the development of *O. Salteri*, there appears to the writer to have been in several branches of the *Olenus* family a similar or parallel evolution, the tail changing from spined triangular to entire rounded, the spines being also often lost on cheeks and axis, the ends of the pleuræ changing from long-spined to rounded, and the glabella often becoming smooth. Examples of this in whole or in part are seen, the writer thinks, in the derivation of *Cyclognathus* from *Peltura*, and further back perhaps from *Leptoplastus*, *Acerocare* perhaps from *Leptoplastus*, *Parabolinella* from *Parabolina*, Misses Crossfield and Skeat's *Peltura punctata* from the Shineton *Triarthrus*. (See last abstract.)

For *Olenus Salteri* the writer would therefore propose the sub-genus *Leptoplastides*, and would include in the same sub-genus the *Acerocare claudicans*, *A. norvegicum*, and *A. paradoxum* of Moberg.

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6. *Report on the Faunal Succession in the Carboniferous Limestone of the South-West of England.*—See Reports, p. 313.

7. *Report on the Exact Significance of Local Terms.*

8. *A Contribution to the Palæontology of the North Derbyshire and Notts Coalfield, or the Southern Part of the North Midland Coalfield. By* A. R. HORWOOD.

A summary was given of the extent and position of the North Midland Coalfield. Allusion was then made to the previous work connected with the palæontology of the district. This was very limited, and the correlation of the Top Hard Coal with the Main Coal of Leicestershire, and of the Black Shale with the Arley Mine of Lancashire, had not been founded on fossil evidence.

Recently the re-survey of the district by the Geological Survey and some important borings had added much to our knowledge of the fossil flora and fauna met with.

As a result of these investigations, and by the aid of a summary of all the previously recorded organic remains from this area, the author was able to arrive at the following conclusions :—

1. That the flora of the Top Hard Coal, as afforded by specimens from Pleasley, indicates that it is of the same age as that of the Main Coal of Leicestershire and South Derbyshire (in both the Western or Moira and Eastern or Cole Orton districts), *i.e.*, of Middle Coal-measure age, occupying a position rather more than midway in that division of the Coal-measures.

2. The fauna of the horizon at Mansfield, Notts, 630 feet above the Top Hard Coal, indicates, as pointed out by Mr. Walcot Gibson, a horizon equivalent to the Gin Mine or Twist Coal of the North Staffordshire Coalfield, *i.e.*, near the top of the Middle Coal-measures and commencement of the Transition series, or Black Band group, which would occupy a position slightly higher. Eastward and above this horizon the whole of the Upper Coal-measures are represented, though feebly developed.

3. The Coal-measures of North Derbyshire are, as a whole, entirely confined to the limits of the Grey or chief coal-bearing series (Lower and Middle Coal-measures), like the Leicestershire and South Derbyshire Coalfield, of which it is a continuation; and none of the Red series (or Transition series and Upper Coal-measures) of the North Staffordshire type are met with in this area west of a line somewhat east of the Nottinghamshire and Derbyshire county boundary between Bolsover and Stanton—though this line probably curves westward in the north, just south of Rotherham, and eastwards, south and south-east of Nottingham.

A summary of the fossil flora and fauna of North Derbyshire and Nottinghamshire, as at present known, was given, with the horizon and locality of the specimens cited. This, though preliminary, was in extension of the work already accomplished in the Leicestershire and South Derbyshire Coalfield, shortly to be published, and in other fields, and supplementary to the work of Ward, Hind, and Stobbs in the North Staffordshire Coalfield on the mollusca and fish fauna of that area, and of Kidston on the fossil floras of Yorkshire and North and South Staffordshire.

9. *Report on the pre-Devonian Beds of the Mendips.*—See Reports, p. 315.

TUESDAY, AUGUST 6.

The following Papers and Reports were read :—

1. *A Catalogue of Destructive Earthquakes. By* Dr. JOHN MILNE, *F.R.S.*

Nearly all our large earthquake catalogues are lists of disturbances which vary greatly in their intensity. Very old registers referred to earthquakes which have devastated towns and cities, but as we approach modern times these large disturbances are altogether outnumbered by tremors which in many cases may not have had sufficient intensity to rattle a window. The admixture of large and small disturbances has had its effect upon the analysis of earthquake statistics. For example, one conclusion to which they lead us is that in modern times seismic activity has greatly increased. To determine whether this and other conclusions which seismologists have reached are to be accepted, a catalogue has been nearly completed which only refers to shocks which have had an intensity sufficient to cause structural damage. These are arranged chronologically and according to countries, whilst the extent of damage each occasioned is indicated by a numeral. One inference is that between 1150 and 1250 large earthquakes were very frequent; the next great increase commenced about the year 1650, and it is still in progress. The material to form this compilation was chiefly obtained from the publications of learned societies in various parts of the world. An attempt was made to obtain information respecting recent earthquakes from our leading daily papers, but this was far too meagre to be of any value. For those who have to insure and proportion rates to risks the value of this catalogue must be self-evident.

2. *Mountain Building and Seismology. By* Professor F. FRECH.

The most important earthquakes are those connected with mountain building. Those produced by the breaking down of continental fragments in the Atlantic and Indian Oceans, of the Alpine and Eurasian chains, or of the Circumpacific mountains and islands belong to types altogether different. The Alpine and Pacific mountains differ from one another in the distribution of earthquakes, faults, and volcanoes. The seismic intensity diminishes with the geological age. The more important earthquakes are principally restricted to regions dislocated in Tertiary times. In the later Palæozoic ranges earthquakes are rare, and in the earlier Palæozoic and Pre-Cambrian masses they are almost entirely wanting.

3. *Report on the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, &c.*—See Reports, p. 325.

4. *Note on a New Section in the Glacial Gravels of Holderness. By* T. SHEPPARD, *F.G.S., and* J. W. STATHER, *F.G.S.*

The North Eastern Railway Company has recently been making some extensive excavations in a hill situated between the well-known Kelsey Hill and Burstwich Gravel Pits, in central Holderness. At the present time the section exposed is probably the finest of its kind in the country. The cutting is made through the heart of the hill, and the exposed section is 1,300 feet long and 45 feet high in the centre, from which the section gradually slopes. The sides of the hill are flanked by boulder clay, and irregular masses also occur at intervals in the gravel. There are two types of boulder clay visible, the upper or Hessle clay, containing a preponderance of Cheviot rocks, and the purple or middle boulder clay with its carboniferous limestones and basalts. The gravels are somewhat similar to those described by Mr. Clement Reid at Kelsey Hill as interglacial, but the present authors consider them to be merely part of the terminal moraine of the North Sea

ice-sheet. In addition to the far-travelled boulders, a lengthy list of marine shells, mostly of an Arctic type, has been compiled, and the species *Cyrena* (*Corbicula*) *fluminalis*, a freshwater form, also abounds. An interesting collection of mammalian remains has been secured, and includes bones of *Elephas primigenius*, Rhinoceros, Walrus, Red Deer, *Bison priscus*, Horse, and *Bos*. Some of these bear evidence of having been gnawed by the Hyæna. It is thought that the shells and mammalian remains have been caught up by the moving ice-mass, and in this way incorporated in the moraine.

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5. *On a Marine Peat from the Union Dock, Liverpool. By* J. Lomas, *F.G.S.*

During excavations in the Union Dock on the Mersey Docks and Harbour Board Estate in the south end of Liverpool a very remarkable peat band was discovered. Reckoning downwards from a datum line 3 feet above Old Dock Sill a section showed:—

Sand with black carbonaceous bands	4 feet.
Peat	6 inches.
Blue clay with rootlets	4 feet.
Sand with thin bands of peat	2 feet 10 inches.
Boulder clay	3 feet 2 inches.
Bunter pebble beds	8 feet +.

The upper peat was entirely composed of marine plants, laminaria predominating. On the fronds were numerous encrusting organisms, such as polyzoa, hydrozoa, the fry of young molluscs, &c.

The lower peat, while consisting mainly of marine plants, contained a few drifted pieces of oak and other land plants.

The sands accompanying the peat resemble those of the Mersey Bar, and besides the quartz which makes up the bulk of the deposit, contain zircon, garnet, tourmaline, dolomite, kyanite, rutile, staurolite, orthoclase felspar, biotite and muscovite, shell fragments, foraminifera, sponge spicules and polyzoa.

The deposit was probably accumulated in a sheltered bay in the old estuary of the Mersey.

The chief interest lies in the fact that peat may be formed from marine as well as from land plants.

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6. *On a hitherto unnoticed Section of the* Amaltheus spinatus *Zone and the Transition Bed in the Middle Lias at Billesdon Coplow, Leicestershire. By* A. R. Horwood.

The author, after alluding to a section published by E. Wilson in the 'Geological Magazine,' 1889, p. 296, of the marlstone in the railway cutting at Tilton, Leicestershire, referred to a statement by that writer regarding it as the only exposure of the *Amaltheus spinatus* zone and Transition bed in the county.

Some recent researches, however, have resulted in the discovery of these beds in a little quarry on the road between Tilton village (some distance from the cutting quoted) and Billesdon Coplow, forming part of the escarpment called Life Hill, and about 700 ft. O.D.

There the very characteristic gasteropod and cephalopod zone of the Transition bed is well developed; and so uniform is this horizon in position and faunal contents that the author wished to see more stress laid on it than had previously been done, as indicating the uppermost beds of the marlstone wherever found, being indeed a safe guide where other beds were wanting to denote this.

Another feature to be noted in the higher part of the Rock-bed, hitherto unnoticed or but little emphasised by previous writers on Liassic geology, was the occurrence of a very well-marked encrinital limestone band, varying from 1 foot to 18 inches, though often less, of a very hard nature, less subject to the

effects of weathering and decomposition than the marlstone itself, which occurs some 3 feet or 4 feet lower in the section. This is to be found also on Tilton Hill, indicating there also the existence of higher beds than previously known. Its composition was much like some forest marbles, entirely differing from that of beds above or below, though traces of a similar structure occurred less regularly, but never as a definite layer or seam, in other parts of the section.

The horizon of Wilson's type specimen of *Eodiadema granulata* had never been definitely ascertained, nor indeed that of the majority of the gasteropods, &c., described by him as coming from Tilton, but found in the débris used in the construction of the East Norton embankment.

The Billesdon Coplow section solved this question, for there the same echinoderm was found with a number of the same genera and species of gasteropoda, cephalopoda, &c. It had also been found by others, and there was an example from Desborough in the Invertebrate Department of the Leicester Museum under the writer's charge.

In conclusion the author wished to reiterate his remarks as to the importance for zonal purposes of this gasteropod band of the Transition bed of the middle lias.

The character of the fauna stamped it decidedly as purely littoral or coastal, whilst that of the beds below, containing as they did chiefly brachiopoda and deeper-water lamellibranchs and cephalopods, pointed to their being of a more pelagic nature.

It marked a change in the physical conditions which predominated at that period, and as such was rightly named a 'Transition bed,' for the Upper Lias fauna was itself only a modification of it, with some differences of lithological composition in the strata and of species in the fauna which characterised it.

Probably the inset of more littoral conditions took place between the formation of the thick encrinital seam mentioned above and that of the Transition bed. Certainly pelagic conditions, judging from the lithology and fauna of the beds below, seemed to come to a close about the time when this encrinital seam was deposited.

The thickness of the strata and the fauna of the two sections, the one at Tilton as described by Wilson and the other as discovered at Billesdon Coplow by the writer, were, with some slight differences, due to local causes, more or less identical.

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7. *On the Occurrence of Boulders of Strontia in the Upper Triassic Marls of Abbots Leigh, near Bristol. By* HERBERT BOLTON, *F.R.S.E., F.G.S., and* C. J. WATERFALL.

A considerable area of the park attached to Leigh Court, near Bristol, has been found to be underlaid by a remarkable deposit of huge boulders of strontia embedded in Triassic marls. The boulders in various places appear above the surface. The soil varies in depth from a few inches to 4 feet, and rests upon the irregular surface of the marl-beds containing strontia. The boulders of strontia are found of all sizes, from a pea up to masses estimated at 100 tons in weight. In one instance the breaking-up of a single boulder of strontia occupied six men for five weeks. Six hundred of tons of the mineral were found in one pit 15 yards long by 21 yards wide.

The upper surface of the boulders is usually deeply grooved, the grooves running approximately north and south. The boulders readily split into slabs along lines coinciding with the grooves. The deposit up to the present has not exceeded a greater depth than 11 feet. The yield of strontia is about 2,000 tons per acre.

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8. *Notes on the Ancient Volcanoes of Basutoland. By* Rev. S. S. DORNAN.

Basutoland is a high plateau between the Vaal and the Orange Rivers. It is the culminating point of the great plateau which fills the whole interior of the

sub-continent. Upon this plateau, as a foundation, stand the great volcanic ranges, more than 11,000 feet high.

From the Caledon River to the edge of the great volcanic plateau is about fifteen miles. This plain is fairly level, and is interspersed with flat-topped mountains rising to 1,500 feet above the plain. These represent the original level of the country. The geology of the country is exceedingly simple. It is filled with the Stormberg series, lying nearly horizontal. The total thickness of these rocks amounts to 6,000 feet, of which the volcanic beds amount to 4,000 feet. The sandstones are loose and friable, and contain remains of plants, dinosaurs, and crocodiles.

The volcanic beds are the most striking rock features of the country, as they compose all the highest summits of the great ranges of mountains known as the Drakensberg and Malöte.

The vents from which the lavas and ash proceeded which have built up these great piles of rock can be roughly arranged in three or four parallel lines, corresponding to the present ranges of mountains. The first range consists of Machache, Thaba 'Telle, &c.; the second of Dikolobeng, Mokhele, &c.; the third of Mount Hamilton and Motai; and the last of the great summits of the Drakensberg, such as Mont aux Sources, Champagne Castle. Most of these mountains are 10,000 feet high and upwards. The rivers run in the synclines between these ranges of mountains, as a glance at the map shows.

The volcanic beds consist of lavas and ashes, with occasional silicious tuffs, intersected with intrusive sheets and dykes. Most of the lavas are amygdaloid; scoriaceous varieties also occur, but they are much less common. The beds are often full of pipe-like vesicles, filled with calcite, but often empty. These vesicles are inclined towards the vent. Basaltic lavas are common, and andesites also occur.

A short description of four of the most prominent peaks will serve as examples of the others.

(1) Thaba 'Telle. It is about 7,800 feet high, with steep—in some places precipitous—sides. It is composed of doleritic amygdaloid lavas, alternating with beds of ash. The plug is agglomerate, evidently the remains of the old throat. The lavas are full of steam holes. Thick deposits of purple ash also occur. Near the base of the mountain is a large intrusive sheet, surrounding what was formerly a subsidiary cone, but is now nothing more than a mere conical plug of agglomerate.

(2) Thaba Tsuen. This mountain is slightly lower than the preceding, but of beautiful conical shape. The height is 7,529 feet. It consists of two terraces and the agglomerate plug. The total thickness of lavas, ashes, and agglomerate is 1,600 feet. The plug proper rises from the second terrace, which slopes gently inwards, indicating the roots of the old cone. The plug is composed of coarse doleritic lava and agglomerate, and is about 500 feet high. It is a prominent landmark, and even more typically volcanic than many of the other peaks. The deposition of the lavas was not continuous, as there are thin intercalated beds of sandstone. The same feature occurs on all the other mountains examined.

(3) Thaba de Noha. This is a portion of the great Mokhele range. The plug and a portion of the old crater-walls remain. The lavas at one point are glassy, and steeply inclined, at another scoriaceous. There are also thick beds of ash. The characteristics of the lavas in this range are similar to the peaks previously mentioned.

(4) Thaba 'Ntso. This mountain is 7,560 feet high. It is part of a great range running perpendicular to the course of the Orange River. The composition of the lava beds is similar to Thaba de Noha, the principal difference being that the beds of ash are thicker and better consolidated, evidently pointing to deposition in deeper water.

Many of the very highest peaks, such as Mont aux Sources, Motai, Mount Hamilton, are not described here, as the writer has never been able to visit them.

A short notice of the intrusive sheets and dykes is a necessary complement to

the description of the lavas. These dykes, &c., are posterior to the volcanic beds which they traverse. None, so far as the writer knows, have the characteristic of a lava flow.

They vary much in size, from a few inches thick and a few yards long, up to 20 feet or more in thickness and several miles in length. Two remarkable examples of the latter kind occur in South Basutoland, near Mohales' Hoek. The dolerite is columnar, and as straight as if laid out artificially. Small displacement of the neighbouring strata is a conspicuous feature of these dykes.

The country owes its present configuration to two series of earth movements: one from west to east and the other from south to north, long afterwards. There is no evidence of denudation before the deposition of the lavas, and the writer is of opinion that the lavas were not all sub-aqueous.

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9. *Second Report on the Crystalline Rocks of Anglesey.*—See Reports, p. 317.

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10. *Report on Life-zones in the British Carboniferous Rocks.* See Reports, p. 316.

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11. *Report on the Erratic Blocks of the British Isles.*—See Reports, p. 329.

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12. *Interim Report on the Correlation and Age of South African Strata, &c.*—See Reports, p. 328.

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13. *Report on the Fossil Flora of the Transvaal.*—See Reports, p. 345.

Section D.—ZOOLOGY.

President of the Section.—William E. Hoyle, M.A., D.Sc.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

The impression left upon my mind by a score of Presidential Addresses to this Section, which it has been my privilege to hear, is that the speaker who treats of the subject matter of his own researches has the best prospect of making his remarks interesting and profitable to his audience. It is therefore in no spirit of egotism that I invite your attention this morning to the small and economically unimportant group of the Cephalopoda.

Some of my predecessors have been men who walked, so to speak, on the heights; who undertook the culture, or at all events the surveillance, of large domains. The extensive views and broad principles which they have thus been able to lay before the Section have been such as at once to compel the attention of all who are interested in any department of biology, or indeed of any branch of science at all. My own case has been far different; the plot I have tried to cultivate has been a very small one, and I have had but little leisure to peep over the fence and see what my neighbours were doing. I come before you, therefore, as a specialist, and not only so, but as that most humble kind of specialist—a systematist (a 'mere systematist' is, I believe, the common phrase)—one whose main work has been the discrimination and definition of genera and species. I feel that some apology is necessary in asking zoologists of all departments to step for an hour into my particular allotment and see what has been going on there during the last few decades.

Before inviting you to enter, however, I should like to plead that even the systematist has his uses; for, properly considered, what is the systematic arrangement of any group of animals but the condensed formal expression of our present knowledge regarding its morphology, ontogeny, and phylogeny? Furthermore, how could the varied and complex problems of geographical distribution be attacked without the materials prepared by the systematist?

Having said this much by way of apology and defence, let me invite you without further prelude to consider two or three questions suggested by the study of the Cephalopoda.

Just half a century ago (August 1, 1857), there appeared in the 'Annals and Magazine of Natural History' the translation of a paper by the late Professor Steenstrup (39)[1] of Copenhagen which has ever since been regarded as marking an epoch in our knowledge of the Cephalopoda. The consideration of the scope and significance of this memoir may profitably engage our attention for a short time. In researches which were then comparatively recent Vérany and Vogt (42) and Heinrich Müller (32) had shown that, in the genera *Tremoctopus* and *Argonauta*, the hectocotylus, a supposed parasitic worm which had been found in the mantle-cavity of the female, was in reality one of the arms of the male

[1] The figures refer to the list of references at the end of the Address.

which had become detached and found its way thither, bearing with it the fertilising element—a procedure quite unique, not only among the Cephalopoda, but also among the Mollusca, if not in the whole animal kingdom. The gist of Steenstrup's discovery was that, although the separation of an arm was peculiar to very few forms, the modification of one or other of the arms for reproductive purposes was of common occurrence among the Cephalopoda; and, furthermore, that the situation of the particular arm, which was so modified, varied with the systematic position of the genus in question, and was constant through the main divisions of the class. To this less extensive modification of the arm he gave the name 'hectocotylisation,' and expressed his conclusions in the following table:—

'OCTOPODA

Philonexidæ	*Argonauta* (Philonexis) *Tremoctopus*	third left / right	arm a Hectocotylus (feminæ polyandræ!)
Octopidæ	*Octopus* *Eledone*	third right arm hectocotylised (feminæ monandræ?)	

DECAPODA.

Myopsidæ	*Rossia*	first left arm hectocotylised	(with the right one, only in the middle)
	Sepiola		(alone in its whole length)
	Sepia	fourth left arm hectocotylised	(at the base)
	Sepioteuthis		(at the apex)
	Loligo		(at the apex)
	Loliolus		(in its whole length)
Oigopsidæ	*Ommatostrephes* *Onychoteuthis* *Loligopsis*	no hectocotylised arm hitherto observed.'	

Stimulated by this discovery, other zoologists examined the Cephalopoda in their possession, and described the modifications in various genera, and now it is universally recognised that no definition of a Cephalopod is complete which does not include a description of the position and form of the hectocotylised arm. The descriptive anatomy of this organ is fairly well known. Out of twenty-two families, which may be regarded as well established, its structure is known in a number of genera in no fewer than twelve, whilst of the remaining ten it has been more or less conclusively shown that in seven no modification of the arm takes place, so that there are only three families in which we are still without any information regarding it.

Our knowledge of the physiology of the apparatus has not, however, advanced with anything like the same rapidity. Even in the case of those forms where a true hectocotylus is found (*Argonauta*, *Tremoctopus*, and *Ocythoë*) it is not known for certain whether the fertilising arm is deposited by the male in the mantle-cavity of the female (as I think is most probable), or whether (as is stated by some writers) the arm breaks off when mature and finds its own way to its destination. This much is certain, that for some time after its detachment it possesses the power of independent movement.

As regards the function of the modified but not detachable arm, we have the important and interesting observations of Racovitza (37) made at Roscoff and Banyuls on the genera *Polypus* (*Octopus*) and *Sepiola*. It appears that in the first of these forms the extremity of the hectocotylised arm of the male is introduced into the mantle-cavity of the female, both individuals resting on the sea-bottom and at some distance from each other (about 25 cm. in the case of a male measuring 1·25 m. in total length). Although after an encounter the female appeared to flee the embraces of the male, and although the males, when two were placed in the same tank, fought with each other, there was no sign of any combat between the sexes as was described by Kollmann (28). In *Sepiola* (36) the female is roughly seized by the male, and held with the ventral surface uppermost; the two dorsal arms are introduced into the mantle-cavity, whilst the other three pairs hold the female firmly. The efforts of the male are directed to

keeping the female from attaching herself to any firm support. It would appear that the introduction of the arms of the male into the mantle-cavity interferes with the respiration of the female, and that she makes desperate efforts to escape as soon as she can attach herself to any neighbouring object. In this respect there is a marked contrast between the behaviour of these two genera, and it is greatly to be desired that observations should be made on other forms, but the difficulties in the way of this have hitherto proved insuperable.

Although, as we have seen, but little is known of the actual working of the hectocotylised arm, there are differences in the structures set apart in the female for the reception of the spermatophores, which correspond with the different arrangements of the hectocotylus in the male. For example, in *Polypus* (*Octopus*) the spermatophores are deposited in the termination of the oviduct; in *Rossia* there is a large plicated area surrounding the mouth of the oviduct for their reception; whilst in the nearly related *Sepiola* there is a pouch-like depression of the integument lying beside the mouth of the oviduct for the same purpose (von Maehrenthal) (29). In *Sepia*, *Loligo*, and the other Myopsids in which the ventral arms are hectocotylised the spermatophores are received upon a specially modified area lying just to the ventral side of the mouth.

From this all too brief sketch of the function of these organs we may now return to the question of the systematic value of the modified arm of the male. Professor Steenstrup was firmly convinced of the paramount importance of the hectocotylisation as a classificatory character, and he seemed to cling to this belief almost with the ardour of a devotee for a religious principle. In 1881 he published a memoir (40) in which a new classification of the genera *Sepia*, *Loligo*, *Rossia*, and some other forms was propounded, based avowedly on the position of the hectocotylised arm; and when this scheme was attacked by the late Dr. Brock of Göttingen (3) he defended it vigorously in a further communication (41), placing at its head the following thesis, much in the same spirit as Luther nailed his famous theses to the church door at Wittenberg: 'Hectocotylatio bene observata et rite considerata divisionibus naturae semper congruit; incongrua divisionibus, eas arbitrarias et factitias esse indicat.'

Steenstrup further explains that the point of most consequence is which pair of arms is affected by the hectocotylisation, whether the first, third, or fourth pair; next in importance comes the nature of the modification; while the question whether the right or left arm is affected is quite insignificant. It will be our business to consider how far the Danish naturalist's position is justified in the light of our present knowledge.

It will first be necessary to set out the facts of the case as ascertained up to the present date, and, as no complete statement is accessible, it will be convenient to give a list of the genera of recent dibranchiate Cephalopods, showing which arm (or arms) is affected by the modification under discussion.

Table I.

List of Genera of Recent Dibranchiate Cephalopoda showing the position of the hectocotylised arm or arms, with an indication of the modification found.

1, 2, 3, 4 = the position of the arm or arms, reckoning from the dorsal to the ventral.
R. and L. = right and left.
0 = no hectocotylised arm is present.
? = no information is at present available.

OCTOPODA.

Cirroteuthidæ.	
Cirroteuthis	0
Stauroteuthis	0
Froekenia	?
Opisthoteuthis	0

Amphitretidæ.

Amphitretus	0

Alloposidæ.

Alloposus	3 R.; presumably caducous.
Bolitæna	?

Argonautidæ.

Argonauta	3 L.; caducous.
Ocythoë	3 R.; caducous.
Tremoctopus	3 R.; caducous.

Polypodidæ.

Polypus (= *Octopus*)	3 R.; spoon-shaped extremity.
Pinnoctopus	?
Cistopus	?
Scæurgus	3 L.; spoon-shaped extremity.
Moschites (= *Eledone*)	3 R.; spoon-shaped extremity.
Eledonella	3 R. and L.; enlarged suckers.
Japetella	?

DECAPODA.

MYOPSIDA.

Idiosepiidæ.

Idiosepius (30, 40)	4 R. and L.; loss of some suckers.

Sepiolidæ.

Sepiola	1 L.; loss of certain suckers, fleshy process near the base, minor changes in other arms.
Inioteuthis	1 L.; distal half thickened, suckers on elongated papillæ, minor changes in other arms.
Euprymna	1 L.; distal portion of arm bears thickened papillæ with degenerate suckers, minor changes in other arms.
Stoloteuthis	1 R. and L.; large crowded suckers at the base; minor changes in other arms.
Heteroteuthis	1, 2, R. and L.; 1 and 2 of either side united by web, 1 and 2 R. with a gland on the inner aspect; minor changes in other arms.
Nectoteuthis	Described as having all the arms modified, but this seems doubtful.
Sepiadarium	4 L.; suckers replaced by transverse ridges in distal portion.
Sepioloidea (3)	4 L.; suckers diminished, transverse ridges in whole arm.
Rossia	1 R. and L; suckers mounted on stout papillæ; glandular enlargements on the arms.
Semirossia	1 L.; similar modification confined to one arm.

Loliginidæ.

Loligo	4 L.; suckers replaced by pointed papillæ at tip.
Sepioteuthis	4 L.; suckers replaced by pointed papillæ at tip.
Loliolus	4 L.; suckers replaced by papillæ the whole length of the arm.
Lolliguncula	?

Sepiidæ.

Sepia	4 L.; suckers diminished and replaced by transverse ridges in proximal portion.
Sepiella	4 L.; suckers diminished and replaced by transverse ridges in proximal portion.
Hemisepius	?

ŒGOPSIDA.

Spirulidæ.	
Spirula (34)	4 R. and L.; arms enlarged and devoid of suckers.
Gonatidæ.	
Gonatus	0
Onychoteuthidæ.	
Onychoteuthis	0
Ancistroteuthis	0
Chaunoteuthis	0
Teleoteuthis	0
Tetronychoteuthis	?
Lycoteuthis	?
Enoploteuthidæ.	
Enoploteuthis	?
Abralia (10)	4 L.; two short parallel longitudinal ridges near the tip, which is devoid of hooks.
Thelidioteuthis	?
Ancistrochirus	?
Pterygioteuthis (6)	4 L.; suckers wanting, two glandular pads near the middle, between which is a dentate plate with a system of delicate lamellæ.
Pyroteuthis (10)	4 R.; a swollen ridge on the dorsal aspect of the tip of the arm produced into a long point.
Abraliopsis (15)	4 L.; an expanded web, with transverse ribs along the ventral aspect of the arm.
Octopodoteuthis	All arms; swollen extremities ??
Cucioteuthus	?
Architeuthidæ.	
Architeuthus	?
Tracheloteuthidæ.	
Tracheloteuthis	0
Bathyteuthidæ.	
Bathyteuthis	0
Ctenopteryx	?
Histioteuthidæ.	
Histioteuthis (7)	1 R. and L.; terminal suckers small on stout columnar papillæ, 4 rows.
Calliteuthis (7)	1 R. and L.; terminal suckers small, on stout columnar papillæ, 2 rows.
Meleagroteuthis	?
Thysanoteuthidæ.	
Thysanoteuthis	?
Ommastrephidæ.	
Ommastrephes (35)	4 L.; terminal suckers modified into papillæ.
Symplectoteuthis	?
Sthenoteuthis	?
Dosidicus	
Illex (35)	4 L. or R.; terminal suckers modified into papillæ.
Todaropsis (12)	4 R. and L.; modification of suckers into papillæ, scale-like processes near base L.
Hyaloteuthis	?
Chiroteuthidæ.	
Chiroteuthis	0
Doratopsis	0
Mastigoteuthis	0

Grimalditeuthidæ.	
Grimalditeuthis	?
Cranchiidæ.	
Cranchia (8)	4 R.; stout, keeled, suckers in four rows, closely packed near the tip; 3 R. and L., with small closely packed suckers.
Liocranchia (8)	4 L.; suckers in a single row at the tip.
Leachia	?
Zygænopsis (8)	4 R.; enlarged with closely packed suckers in two rows.
Taonius	?
Corynomma	?
Crystalloteuthis	?
Sandalops	?
Toxeuma	?
Bathothauma	?

The following genera, whose systematic position is uncertain, or whose validity is doubtful, have been omitted: *Tritaxeopus*, *Hoylea*, *Promachoteuthis*, *Compsoteuthis*, *Micrabralia*, *Thaumatolampas*, *Brachioteuthis*, *Stigmatoteuthis*, *Chiroteuthopsis*, *Galiteuthis*, *Desmoteuthis*, *Owenia*, *Taonidium*.

An inspection of this table shows, first of all, that where hectocotylisation is known to take place it affects either the first, third, or fourth pair of arms; no instance is yet known where the second pair is modified, except in subsidiary relation to another pair, or in one or two rather doubtful cases in which all the arms are said to be modified. It appears, furthermore, that hectocotylisation of the third pair is confined to the Octopoda, whilst the first and fourth pairs are affected in the Decapoda, so that, as far as the main divisions of the Dibranchiata are concerned, the position of the hectocotylus is a correct index to them. We may, however, go a step further still, and point out that in every family, with one exception, the position of the hectocotylised arm is constant within the limits of the family, so that there is a very strong *prima facie* case for the truth of Professor Steenstrup's dictum. The difficulty arises when we come to consider the family Sepiolidæ and its allies, and endeavour to form an idea of their relationships to each other.

Steenstrup was so convinced of the truth of his thesis that he classified the Myopsida thus:—

SEPIOLINI.		
	Sepiola	1 L.
	Rossia	1 L. & R.
	Heteroteuthis	1 L. & R.
SEPIO-LOLIGINEI.		
Eusepii.		
	Sepia	4 L.
	Sepiella	4 L.
	Hemisepius	?
Sepiadarii.		
	Sepiadarium	4 L.
	Sepioloidea	4 L.
Idiosepii.		
	Idiosepius	4 R. & L.
	Spirula	4 R. & L.
Loliginei.		
	Sepioteuthis	4 L.
	Loligo	4 L.
	Loliolus	4 L.

He thus made two main divisions according to whether hectocotylisation affected the first or fourth pair of arms, and placed the four genera *Sepiadarium*, *Sepioloidea*, and *Idiosepius* (notwithstanding their *Sepiola*-like form) with *Spirula*, apart from *Sepiola* and *Rossia*, and along with *Sepia* and *Loligo*. It becomes necessary now to inquire how far this classification is justified by what we know of the morphology of the forms concerned.

It will be convenient to deal in the first place with *Spirula*, which has always been of great interest on account of the unique structure and position of its shell. It still belongs to the greatest of zoological varieties, only a dozen specimens with the soft parts having been obtained, of which one alone proved to be a male. This was examined by Sir Richard Owen (34), who described the hectocotylisation as affecting both the ventral arms, which are much enlarged, exceeding the others both in length and thickness: they are quadrangular in section, devoid of suckers, and the right is much larger than the left. The other arms appear to have a round truncated extremity which may be a secondary modification. The relationships of *Spirula* have recently been made the subject of inquiry by Professor Paul Pelseneer, who completed the memoir in the 'Challenger' reports begun by Professor Huxley (17), and by Dr. Einar Lönnberg (30) of Stockholm, who dissected a specimen obtained for him from Madeira by the late Captain Eckman. These two investigators arrived at different conclusions regarding its systematic position.

Pelseneer regards it as an Œgopsid on the strength of the following characters:—

1. The open eyelids admitting the sea-water to bathe the cornea.
2. The elongated central nervous system.
3. The short junction of the visceral nerves behind the anus. (It may be noted that Myopsids vary in this respect.)
4. The well-developed anterior salivary glands. (Here it must be remembered that these glands are present in *Rossia* and not in *Sepiola*.)
5. The liver is not traversed by the œsophagus. (Here, again, the Myopsids vary.)
6. The posterior aorta has a recurrent branch.
7. The renal aperture is sessile, not mounted on a papilla. (Yet several Œgopsid genera, e.g., *Thysanoteuthis*, *Histioteuthis*, *Chiroteuthis*, and *Mastigoteuthis*, have renal papillæ.)
8. The tentacular arms are incompletely retractile.

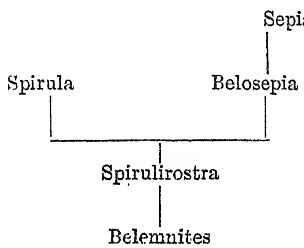
The following may be mentioned as Myopsid characters in *Spirula*:—

1. The single oviduct on the left side.
2. The arrangement of the lamellæ in the nidamental gland resembles that in *Sepia* and *Loligo*.
3. All Œgopsids (except *Gonatus*) have the suckers in two rows, whereas *Spirula* has more.
4. Both ventral arms are devoid of suckers, which in *Idiosepius* are much reduced in number. (Steenstrup says to one.)
5. The body is elongated and cylindrical, as in *Idiosepius*.
6. The fins are rudimentary, and terminal also, as in *Idiosepius*.
7. The terminal pit in *Spirula* is compared with a similarly situated depression in *Idiosepius*.

The last three characters are adduced by Steenstrup to justify his inclusion of *Spirula* and *Idiosepius* in the same family, but they can hardly be regarded as of great importance. The form of the body and position of the fins are easily modified in response to environment; the depression in the posterior extremity of *Idiosepius* does not seem to be constant, whilst, as regards the resemblance of the hectocotylised arms, it is, in my opinion, more apparent than real. In *Spirula* the ventral arms are much enlarged, quadrangular, and suckerless; in *Idiosepius* they are

similar in size and form to the other arms. The suckers, according to Steenstrup, are reduced to one on each arm; but so small a number has not been found in any of the specimens subsequently examined; and in any case diminution in the number of suckers in the hectocotylised arm is by no means an uncommon phenomenon. Compare, for example, *Sepia*, *Todaropsis*, *Sepioloidea*. When we consider the absence of the shell in *Idiosepius*, and its size and character in *Spirula*, we must, I think, conclude that, at any rate, these two forms cannot be so closely related to each other as to belong to the same sub-family, or even family.

With regard to the question at issue between Pelseneer and Lönnberg as to the Œgopsid or Myopsid nature of *Spirula*, I think, on the whole, that its resemblance is to the former rather than to the latter; but I believe that the branch of the ancestral tree which terminates in *Spirula* was given off from the main Cephalopod stem before the Œgopsida and Myopsida, as we now know them, had been separately evolved. Palæontology reveals a possible descent of *Spirula* from a Belemnitoid through such an intermediate form as *Spirulirostra*; and from this, on the other hand, it is easy to conceive of the descent of *Sepia* through a form resembling *Belosepia*. Such a relation could be expressed by the following diagram, which is, however, only a rough illustration of possibilities, for *Spirulirostra* is a miocene form and *Belosepia* an eocene, so that the former could hardly be the ancestor of the latter. It is only contended that these forms indicate a possible line of descent.



Unfortunately, in the present state of our knowledge, it is impossible to correlate the above diagram with one based upon the study of the soft parts of recent forms. It is sufficient if they do not contradict each other. We know nothing of the soft parts of the fossils, and there is no recent form, which exhibits shell characters, bridging over the gulf between *Sepia* and *Spirula*. To sum up, *Spirula* must be regarded as, at all events, the representative of a distinct family: it it is not unlikely that it may one day become the type of a division coequal with Myopsida and Œgopsida, and it does not appear to me that the structure of its hectocotylised arms would be any argument against such a view.

We may now consider the genera *Idiosepius*, *Sepiadarium*, and *Sepioloidea*. *Idiosepius* has the following characters:—

1. The shell is wanting.
2. The connection between the mantle and head resembles that of *Sepiola*, but is in a transition state.
3. The fins are circular; rather posterior in position.
4. There are no siphonal adductors visible externally.
5. Pallial adductors are present.
6. The pallial nerve is divided into two branches for a short distance; the stellate ganglion is elongated.
7. The liver capsule is completely closed.
8. There are small anterior salivary glands, as in *Rossia*; the posterior are separated, as in *Sepiola*.
9. The testicular canals are radially disposed about a round superficial depression.
10. Both ventral arms are hectocotylised, the suckers being reduced to 4, 3, 2, or 1, and the spermatophores are attached to the buccal membrane.

11. A rudiment of the right oviduct is present.

Sepiadarium agrees with *Idiosepius* in numbers 1, 4, 5, 7, and 9; in regard to the other points its position is:—

2. The connection of the mantle and head resembles that of *Sepiola*; a rudimentary cartilage is present; the mantle is fused with the base of the funnel on either side.
3. The fins are sub-circular, situated half-way back along the mantle.
6. The pallial nerve is unbranched, and traverses the stellate ganglion.
8. There are small anterior salivary glands, and the posterior are fused as in *Rossia*.
10. The left ventral arm is hectocotylised at the tip, and the spermatophores are attached to the buccal membrane.
11. There is a single left oviduct.

Sepioloidea is very inadequately known, but it agrees very closely with *Sepiadarium* in those parts which have been investigated.

There can be no question that the above assemblage of characters allies these three genera to the Sepiolidæ rather than to the Sepiidæ or Loliginidæ; in fact practically the only character of any importance which points in the opposite direction is the hectocotylisation. This portion of the subject has been very fully and clearly handled by Dr. Appellöf of Bergen (1), and to his memoir I refer those who desire more detailed information. We have here, then, a case in which forms whose ventral arms are hectocotylised are more nearly related to forms with dorsal hectocotylisation than to others with ventral, and this shows that the position of the modified arm (or arms) is not by itself an infallible guide to systematic affinity. It is a striking instance of an aphorism of the late Professor Rolleston, that 'no single character can be regarded as a safe basis for a natural classification until it has been proved to be so.'

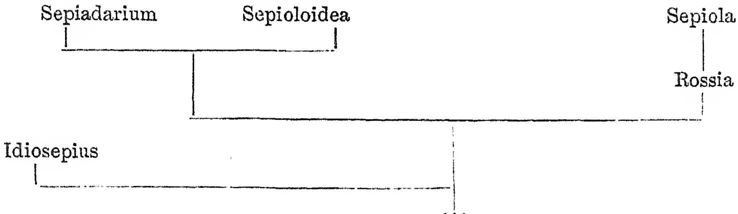
It may, however, be worth while to look a little further into the relationships of these forms, and to see whether the hectocotylisation of the dorsal arms is quite as sporadic and irregular as it at first appears. It must be remembered that in by far the larger number of the Decapoda the hectocotylisation affects the ventral pair of arms. If we take the possible lines of development of this group, we must, I think, admit that the Œgopsida are more primitive than the Myopsida; the paired oviducts furnish the most obvious proof of this. The closure of the ocular aperture would seem to have been the first step in the evolution of the Myopsida, for this character is present in the group without any exception. This primitive Myopsid stem divided into two branches (2). With one, leading to *Loligo* and *Sepia*, we need not concern ourselves further. The other gave rise to the group of forms we are at present considering. These seem to have had a short stumpy body and sub-circular fins; the right oviduct was gradually becoming abortive, and the shell was undergoing atrophy; the mantle was still connected with the back of the neck by a cartilaginous joint; a complete muscular liver capsule was being formed; the posterior salivary glands were fused, and the hectocotylisation affected the ventral pair of arms. The next step in differentiation was the separation of a branch leading to *Idiosepius* which was given off before the right oviduct had entirely disappeared, and still showed a primitive character in the posterior situation of the fins. It must, however, have acquired independently the fusion of the mantle with the head in the nuchal region, and the separation of the posterior salivary glands; for though these reappear in other members of the family, they are not found in *Rossia*.

As to the further evolution of this group two possibilities present themselves:—

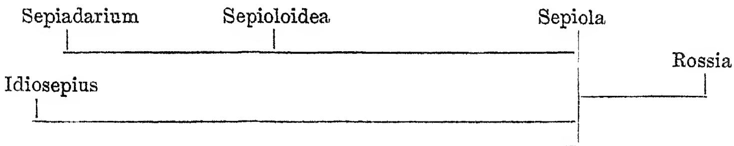
A. The main stem divided into two branches leading to *Rossia* and *Sepiola* on the one hand, and to *Sepiadarium* and *Sepioloidea* on the other.

B. The stem gave off first a branch leading to *Rossia*, and subsequently divided into two, one leading to *Sepiola* and the other to *Sepiadarium* and *Sepioloidea*.

These two alternatives may be expressed graphically thus:—



(A)



(B)

These schemes are not entirely satisfactory. Certain difficulties are common to them both. The posterior salivary glands, which, it is assumed, were inherited in a fused condition from the primitive Œgopsid stem, and remain in that condition in *Rossia,* have been separated in *Idiosepius, Sepiadarium,* and *Sepiola,* as well as in *Sepia* and *Loligo.*

Furthermore, A presents the difficulty that the fusion of the mantle with the head in the nuchal region has been acquired independently by *Idiosepius, Sepiadarium* and *Sepioloidea,* and *Sepiola.*

On the other hand, B has the disadvantage of assuming that the hectocotylisation has been transferred from the fourth to the first pair of arms independently in *Rossia* and *Sepiola.*

On the whole it would appear that this is the greater difficulty of the two, for variations in the connections of the mantle are known to occur in other groups. For example, in the whole family of the Cranchiidæ the mantle is fused with the head in the dorsal middle line, and is also united with the base of the funnel on either side. A similar union is found in *Sepiadarium,* though it does not occur in the allied *Sepioloidea.* Again, in *Symplectoteuthis oualaniensis* a similar connection between the mantle and the base of the funnel occurs, though it is not found in any of the allied genera. If scheme A is admitted to offer the lesser of the two difficulties, it has the advantage of indicating that the hectocotylisation of the ventral arms has been directly inherited from the main stem common to Myopsids and Œgopsids, and has only been transferred to the dorsal arms in the branch common to *Rossia* and *Sepiola.* One other instance has recently come to light in which the hectocotylisation has been transferred from the ventral to the dorsal arms; I allude to the genera *Calliteuthis* and *Histioteuthis* (7) among the Œgopsida: they constitute the sole instance in this sub-order in which the hectocotylisation affects any other than the ventral pair of arms.

On the whole we reach the conclusion that, although the variations in the structure and position of the hectocotylus follow pretty closely the systematic divisions of the Dibranchiata, we are not justified in maintaining that the position of the hectocotylised arm is by itself a sufficient guide to the systematic position of a doubtful form; it is only one of many characters that must be taken into consideration.

The subject of fossil Cephalopoda has not formed any part of my own special researches, but a contribution has recently been made to our knowledge of these forms to which it seems desirable to allude, because it deals, not with systematic or stratigraphical facts, but with conclusions which may be drawn from shell structure as to the life-history and habits of certain important and interesting forms.

Professor Jaekel (19), formerly of Berlin, now of Greifswald, the author of the memoir referred to, lays down a number of theses regarding the organisation and mode of life of these extinct species, and I venture to give an abstract of his views, premising that my acquaintance with palæontology does not justify me in expressing a definite opinion as to the validity of his conclusions, though they seem extremely reasonable.

His opening statement is that *Orthoceras* and its allies were not free-swimming but sessile organisms, and this is based on the following arguments amongst others. The shells were thicker and heavier than any that are found in pelagic organisms; the external sculpture shows that the shell was not embedded in the soft parts, and if it were exposed the annulate arrangement of many forms is inconsistent with their easy passage through the water; the 'lines' (in the naval architect's sense of the word) of an organism intended for navigation are always smooth and not wavy; otherwise undue friction against the water would be created; whilst the straight transverse margin of the aperture of the shell shows that it was not carried by a creeping body like that of a snail. Their sessile nature is further shown in the first place by the radial symmetry, which is rare in free-swimming forms, and almost unknown in those whose axis is long in proportion to their diameter. Further, the termination of the shell is generally broken off: of all the thousands of specimens which have been examined, but very few show the initial chamber; in those cases in which the apex is preserved it shows a scar, where the siphuncle entered the protoconch. The separation of the shell into chambers by transverse septa occurs only in sessile forms, but in such it is found in many divisions of the animal kingdom; for example, Corals, Chœtetidæ (among Polyzoa), *Hippurites* and *Vermetus* (among Mollusca), and *Richthofenia* (among Brachiopoda?). The reason of this cameration is to be found in a constant effort to keep the body of the animal above the surface of the mud in which it is rooted. On this view the siphuncle admits of a simple explanation; it is the vestigial part of the body which has been contracted and partially cut off as the body has moved successively forward to the enlarged superior portion of the shell. In harmony with this is the fact that the siphuncle is wider in the more primitive forms; the name 'siphuncle' on this theory is rather a misnomer, for it is not in the usual sense of the word a 'siphon.' The expansion of the siphuncle in the chambers is explained by the need for diminishing the air spaces so as to increase the weight and consequent stability of the organism.

The fossils known as *Conularia* were probably a primitive form of the same kind, and possibly even belong to the ancestral line of the Cephalopoda. They were conical shells of chitin or conchiolin, radially symmetrical with internal transverse septa, and are commonly found broken off at the apex. A recent observation of Ruedemann (38) has shown that they are sessile, a group of them branching out from a common support. It may be added that J. M. Clarke (9) has recorded a case in the American Upper Devonian rocks in which the majority of the large Orthoceratidæ were fossilised in a vertical or but slightly sloping position.

According to this view the coiled Nautilidæ were free-living forms like the *Nautilus* of to-day, and were probably free from the outset, for they could scarcely have been derived by gradual bending from a straight *Orthoceras*. The half-coiled forms have been derived from the coiled, not from the straight. The forms such as *Phragmoceras*, &c., in which the aperture of the shell is contracted, and often shows bilaterally symmetrical notches, are interpreted as having lived buried in the mud. The notches served for the protrusion of the arms, vent, and siphon, which latter were probably elongated tubes stretching up through apertures excavated in the mud, much in the same way as the heart-urchin (*Echinocardium*) among the sea-urchins lives buried in the mud, and obtains nourishment by stretching its tube feet up to its surface. The arrangement of the arms was probably like that seen in the embryos of Dibranchiata, or of the circumoral appendages of *Nautilus*.

Turning to the extensive and interesting group of Belemnites, Professor Jaekel enunciates the view that these were not, as has been commonly believed, active free-swimming forms, the rostrum (guard serving as the pointed ram of a battleship,

but stationary, the rostrum playing the part of a pile by which they were rooted in the mud at the sea-bottom, like the pointed base of a *Flabellum* or other deep-sea coral, or the anchor-spicules of a glass-rope sponge. In favour of this view may be adduced the size, weight, and solidity of the rostrum, which, if the animal moved about in a horizontal attitude, would have thrown its centre of gravity too far towards that end of the body: its circular section, which points to a radial, not a bilateral, symmetry, and hence, as above mentioned, to a sessile rather than a free-swimming habit. The pointed form of the rostrum would be admirably adapted to fixation in a muddy bottom, whilst its weight would render it a very effective anchor. Further, it is to be noted that Belemnites are found abundantly in strata of argillaceous origin.

This view has a strong recommendation in the fact that it presupposes gradual progress in the Cephalopoda in the direction of greater mobility as evolution advanced, thus:—

A. Orthoceras—firmly attached.
B. Belemnites—anchored in the mud.
C. Recent Dibranchiata—free-swimming.

In regard to the question thus raised of the origin of the present race of pelagic Dibranchiates with (comparatively speaking) rudimentary shells, attention may be directed to a very remarkable and interesting memoir which has just appeared (May 17 of this year) by Dr. Werner Marchand (31) of Leipzig. This contains a descriptive and comparative account of the male internal conducting apparatus, shows how in all cases this may be referred to a common plan of structure, and finally reaches the conclusion that 'the living pelagic Dibranchiates with separated sexes and vestigial shells were derived from non-pelagic hermaphrodite ancestors with elongated bodies and elongated shells.' How far back in time we must travel to find these hermaphrodite ancestors is, of course, unknown; whether they could be found among *Orthoceras* and its allies we have at present no means of ascertaining. Although many authorities believe that certain differences in the shells of Ammonites indicate sexual differences, there is not, so far as I am aware, any evidence of such in the Orthoceratitidæ.

Another interesting discovery of Professor Jaekel (18) is that of a slab of Solenhofen stone, upon which are certain specially arranged impressions, apparently made by the hooks on the arms of a Cephalopod. If this determination is correct, the fact is of the greatest interest, for it would show that these animals walked upon the ground with the head downwards and the distal extremity of the body elevated; that in them the arms were not merely morphologically, but also functionally, the equivalent of a foot.

In conclusion let me direct your attention to a subject which is almost entirely the growth of the last fifteen years. I mean the discovery and investigation of luminous organs in the Cephalopoda. These have now been observed in no fewer than twenty-nine out of about seventy well-characterised genera of Decapoda, and have been found to present a most interesting variety in position and in structure.

Before passing on, however, to consider the structure of these organs it may be well to lay before you the evidence on the strength of which a photogenic function has been ascribed to them. The actual observations are remarkable chiefly for their paucity; indeed, it may seem to some that the foundation of solid fact is too slender for the superstructure raised upon it, but still due consideration will show that this is not the case. The first recorded occurrence of phosphorescence in the Cephalopoda is due to Vérany (42), and dates back rather more than seventy years, though it was not published till 1851. The description is so definite and concise as to be well worth quoting:—

'As often as other engagements permitted, I watched the fishing carried on by the dredge on the shingly beaches which extend from the town of Nice to the mouth of the Var. On the afternoon of September 7, 1834, I arrived at the beach when the dredge had just been drawn in, and saw in the hands of a child

a cuttle-fish, unfortunately greatly damaged. I was so struck by the singularity of its form and the brilliance of its colour that I at once secured it, and, showing it to the fishermen, asked whether they were acquainted with it. Upon their replying in the negative I called their special attention to it, and offered a handsome reward for the next specimen secured, either alive or in good condition, and then passed on to other fishermen and repeated my promise. Shortly afterwards I was summoned and shown a specimen clinging to the net, which I seized and placed in a vessel of water. At that moment I enjoyed the astonishing spectacle of the brilliant spots, which appeared upon the skin of this animal, whose remarkable form had already impressed me: sometimes it was a ray of sapphire blue which blinded me; sometimes of opalescent topaz yellow, which rendered it still more striking; at other times these two rich colours mingled their magnificent rays. During the night these opalescent spots emitted a phosphorescent brilliance which rendered this mollusc one of the most splendid of Nature's products. Its existence was, however, of short duration, though I had placed it in a large vessel of water. Probably it lives at great depths.'

The species thus referred to was *Histioteuthis bonelliana*, which we shall have occasion to refer to in the sequel.

The next observation, so far as I am aware, was made by Professor Chun (4), on board the 'Valdivia' during the German deep-sea expedition, on a form which he has called *Thaumatolampas diadema*. The specimen captured lived long enough to allow of a photograph being made of it whilst in a state of functional activity, and the appearance it presented is thus described by the observer:—

'Among all the marvels of coloration which the animals of the deep sea exhibited to us nothing can be even distantly compared with the hues of these organs. One would think that the body was adorned with a diadem of brilliant gems. The middle organs of the eyes shone with ultramarine-blue, the lateral ones with a pearly sheen. Those towards the front of the lower surface of the body gave out a ruby-red light, while those behind were snow-white or pearly, except the median one, which was sky-blue. It was indeed a glorious spectacle.'

Finally we have the genera *Heteroteuthis* and *Sepiola* the phosphorescent properties of which were seen last year by Dr. W. T. Meyer (32) and Dr. W. Marchand in the Zoological Station at Naples.

This short list comprises all the actual observations on the luminosity of these animals; in these, however, the photogenic function has been definitely associated with special organs, and it is by comparison with these that other organs in other species have been regarded as having the same significance.

The history of the anatomical examination of these organs dates back only to the early nineties, and, so far as I can ascertain, the right of priority of the discovery rests with Professor Joubin (22), who made a communication to the Société scientifique et médicale de l'Ouest at Rennes on February 3, 1893, a brief account of which was published by the Société de Biologie of Paris on the 10th of the same month: this communication related to *Histioteuthis rüppelli*, and in it attention was called to Vérany's observation quoted above. Sections of the organs of *Abraliopsis* were exhibited at the Göttingen meeting of the German Zoological Society and at the Nottingham meeting of this Association in the same year (13). Successive memoirs by Joubin (23–27) and others followed, and in 1903 Professor Chun (5) delivered an address to the German Zoological Society at Würzburg in which he gave a masterly survey of the whole subject, brought forward instances of similar organs previously overlooked, and showed the great variety in structure, not only in the organs of different species, but even in organs of one and the same individual.

More or less adequately authenticated luminous organs have now been recorded in no fewer than thirty-three species of Cephalopoda, and it may be convenient here to give a list of these, with a concise indication of the position in which the organs in question occur.

Table II.

List of the Species of Luminous Cephalopoda with reference to the describer of the organs and an indication of their position.

OCTOPODA.

No luminous organs whatever have hitherto been recorded in this sub-order.

DECAPODA.

MYOPSIDA.

Sepiolidæ.		
Sepiola rondeleti	Meyer (32)	Glandular organ just behind funnel.
Heteroteuthis dispar	„	Glandular organ just behind funnel.
Rossia macrosoma	„	Glandular organ just behind funnel.

ŒGOPSIDA.

Enoploteuthidæ.		
Abralia oweni.	Joubin (25)	Ventral aspect of mantle; siphon head and arms.
Thelidioteuthis polyonyx	Pfeffer (35)	Ventral aspect of mantle; tentacles.
Ancistrochirus lesueuri	Hoyle (16)	Ventral aspect of mantle.
Pterygioteuthis giardi	Hoyle (15), Chun (5)	Mantle-cavity; eyes.
Pyroteuthis margaritifera	Hoyle (14)	Mantle-cavity; eyes.
Abraliopsis hoylei	Hoyle (15), Chun (5)	Ventral surface of mantle; arms.
Thaumatolampas diadema	Chun (4, 5)	Mantle-cavity; arms; tentacles; eyeball.
Onychoteuthidæ.		
Onychoteuthis banksi	Hoyle	Mantle-cavity.
Bathyteuthidæ.		
Bathyteuthis abyssicola	Chun (5)	Dorsal arms; eye.
Histioteuthidæ.		
Histioteuthis rüppelli	Joubin (22)	Ventral aspect of mantle, siphon, head and arms.
Histioteuthis bonelliana	Joubin (24)	Ventral aspect of mantle, siphon, head and arms.
Calliteuthis reversa	Chun (5)	Ventral aspect of mantle, siphon, head and arms
Meleagroteuthis sp.	Pfeffer (35), Joubin (27)	Ventral aspect of mantle, siphon, head and arms.
Chiroteuthidæ.		
Chiroteuthis veranyi	Joubin (20), Chun (5)	Mantle-cavity; arms.
Chiroteuthis picteti	Chun (5)	„ „ „
Chiroteuthopsis talismani?	Fischer and Joubin (11)	Ventral surface of fin.
Chiroteuthopsis grimaldii	Fischer and Joubin (11)	Dorsal surface of fin; ventral surface of head.
Mastigoteuthis sp.?	Chun (5)	Whole surface of integument.

Cranchiidæ

Liocranchia sp.	Chun (8)	Ventral aspect of eyes.
Cranchia sp.	Chun (8)	Ventral and dorsal aspect of eyes.
Leachia cyclura	Joubin (26), Chun (8)	Ventral aspect of eyes.
Leachia eschscholtzi	Chun (8)	,, ,, ,,
Taonius pavo	Chun (8)	,, ,, ,,
Desmoteuthis hyperborea	Chun (8)	,, ,, ,,
Corynomma speculator	Chun (8)	,, ,, ,,
Crystalloteuthis glacialis	Chun (8)	,, ,, ,,
Sandalops melancholicus	Chun (8)	,, ,, ,,
Toxeuma belone	Chun (8)	,, ,, ,,
Taonidium suhmi?	Chun (8)	,, ,, ,,
Bathothauma lyromma	Chun (8)	,, ,, ,,

From this table it would appear that luminous organs occur in the following situations:—

1. Ventral surface of mantle.
2. Ventral surface of body-wall within the mantle-cavity.
3. Ventral surface of siphon.
4. Ventral surface of head.
5. Ventral surface of arms (usually confined to the ventral and ventro-lateral, rarely found on the dorso-lateral, and very rarely on the dorsal).
6. Ventral surface of eyeball.
7. Ventral surface of tentacles.
8. Dorsal aspect of the dorsal arms.
9. Dorsal surface of fin.

The most striking fact apparent from this summary is that luminous organs are practically confined to the ventral aspect of the animal. Another remarkable fact is the existence of organs concealed beneath the mantle and beneath the integument covering the eyeball, which can only be effective by reason of the transparence of the tissues in the living creature.

To give a detailed description of the structure of these many and varied organs would be out of place on the present occasion; it must suffice to group them into more or less well-defined classes and take an example from each.

The luminous organs of Cephalopoda may be divided in the first instance into

A. Glandular.
B. Non-glandular.

A. *Glandular Organs.*—In this class we have to deal only with the type of structure found in *Heteroteuthis*, *Sepiola*, and *Rossia*, which has been investigated by Dr. W. T. Meyer (32) of Hamburg, a pupil of Professor Chun. When working at the Naples Zoological Station he was fortunate enough to obtain a specimen of *Heteroteuthis dispar*, and Dr. Lo Bianco called his attention to its luminous properties. On examination in a dark room it was easy to see the organ lying on the ventral surface of the body, just behind the funnel, showing through the transparent mantle with a pale-greenish light like that of glowworm. It appeared, further, that when the animal was irritated it shot rapidly through the water, leaving behind it a trail of luminous secretion which floated in the form of separate globules, and were afterwards drawn out by the currents into long threads. Dr. Meyer was able to repeat this exhibition of fireworks several times.

In *Sepiola* the luminous secretion is not ejected, but remains attached to the surface of the gland; and, furthermore, the light is only given off on powerful stimulation, as, for example, when the mantle is cut open. The structure of these organs has as yet been only very briefly described by their discoverer: they consist of paired glands, situated as above described one on either side of the anus, and partially concealed by the lateral margin of the ink-sac, which forms a recess for their reception. Beneath and to the inner side of the gland there is a reflector,

and above it is a rounded gelatinous mass, fibrous in structure, transparent during life, covered with a delicate muscular layer. Dr. Meyer hesitates as to the function of this mass; but I think, in view of the structure of the luminous organs in other species, we may hazard the suggestion that it is some kind of lens. This organ is of particular interest, because it is the only instance yet recorded of a luminous organ among the Myopsida and the only glandular luminous organ in the Cephalopoda. Glandular luminous organs are, however, known in many species of fish, and in *Pholas* among the Mollusca.

B. *Non-glandular Organs.*—These may perhaps be divided into

(i) Simple, without special optical apparatus.
(ii) Complex, with more or fewer of the following structures: pigment layer, reflector, lens, diaphragm.

(i) As a type of the simpler kind we may take the branchial organ of *Pterygioteuthis giardi* (15), in which we have a central mass of parenchymatous tissue, with a delicate superficial membrane (consisting of two thin layers), and resting upon a rather thick layer of close, compact tissue, which stains very deeply; beneath this organ is a single layer of cells containing a reddish-brown pigment. The corresponding organ in the nearly allied *Pyroteuthis* (or *Pterygioteuthis*) *margaritifera* (14) is a degree more complex, for underneath the central cell mass is a thick layer of scale-like bodies, similar in structure to that regarded in other cases as a reflector ('tapetum' of Chun). In both these cases it seems necessary to regard the central cells as the source of light (see fig. A).

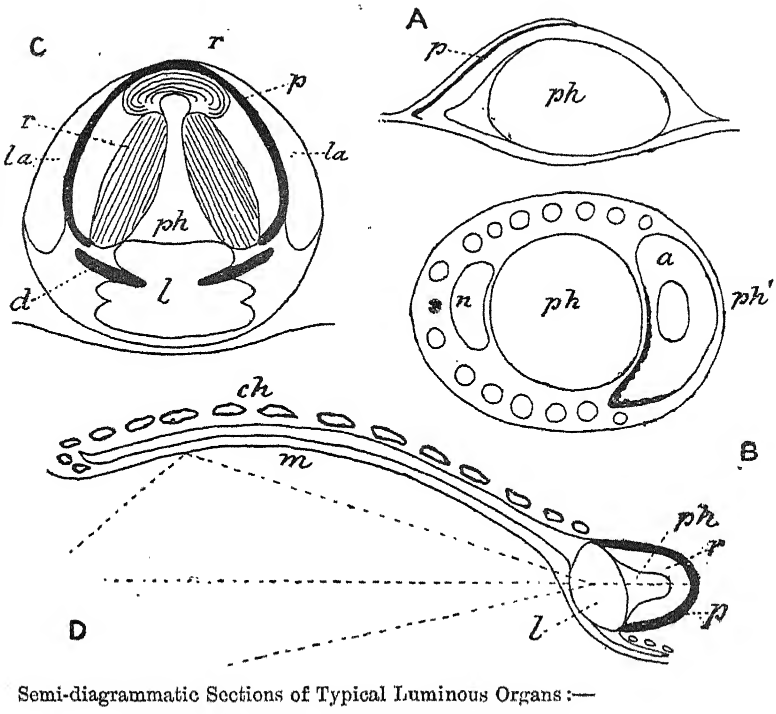
Another organ, almost equally simple, is that found in the tentacles of *Thaumatolampas* (5), where the central portion of the stem of the tentacle for about 2 mm. of its length is occupied by a large rounded cell-mass whose diameter is more than half that of the tentacle. The nerve which usually occupies this position is pushed to one side and flattened out like a ribband. Most curious is the fact that on the side opposite to the nerve a second organ is superposed on the first, which is of more complex structure, inasmuch as it has in its centre a mass of photogenic cells surrounded by a system of radiating fibrils with a pigment layer and tapetum at one side (see fig. B).

(ii) As an example of the complex organs we may conveniently take those of *Histioteuthis rüppelli* (22), where they are scattered over the ventral surface of the mantle, siphon, head, and arms, forming in particular a definite ring round the ventral half of the margin of the ocular aperture. The organ itself is an ovoid body, about 1 mm. in length and somewhat less in diameter. The deeper three-fourths of this cup are covered with a thin layer of pigment, which is lined with a thick coating made up of small lenticular bodies packed closely together and forming a kind of mirror. The space within this, equal in diameter to about half the diameter of the organ, is filled with a mass of large deeply staining cells with large distinct nuclei. The more superficial portion of the organ is made up of what seem to be refractive structures. The deeper portion is conical, fitting into a hollow in the photogenic mass, whilst the upper part is bounded by a definite convex surface the function of which is obviously lenticular. Nerves have been traced passing through the mirror to the light-producing cells in the centre. This ovoid body is situated at the posterior end of a somewhat hollowed patch of an elongated oval shape, which may measure as much as 10–12 mm. in its antero-posterior diameter. A consideration of the form and position of this hollowed patch and of its relation to the axis of the organ shows pretty clearly that it is an external mirror, destined to throw the rays of light downwards and forwards (see fig. D).

One of the most complicated organs known is that found in the mantle of *Abraliopsis* (15). Here the whole apparatus is spheroidal in form and surrounded by a black coating, derived apparently from a number of confluent chromatophores. The photogenic cells lie rather in front of the centre, and before them again a ring of black cells seems to discharge the functions of an iris diaphragm. Behind the source of light is a reflector consisting of two parts: the deeper is concave, spheroidal, and made up of numerous concentric layers; the more superficial

portion is conical, and also composed of concentric lamellæ. Partly in front of and partly behind the diaphragm is a lenticular mass of tissue. These little lanterns are scattered in considerable numbers over the ventral surface of the mantle, funnel, head, and arms, and the appearance of the animal when they are functionally active must be brilliant in the extreme (see fig. C).

If we examine the organs just described and the others above enumerated we see that certain conditions are fulfilled in all cases—namely, the presence of a mass of deeply staining, active cells with distinct nuclei, supplied with blood



Semi-diagrammatic Sections of Typical Luminous Organs:—

A. Branchial organs of *Pterygioteuthis giardi.*
B. Tentacular organs of *Thaumatolampas.*
C. Pallial organ of *Abraliopsis.*
D. Pallial organ of *Histioteuthis rüppelli.*

a. Accessory tentacular organ.
ch. Chromatophores.
d. Diaphragm.
l. Lens.
la. Lacuna.
m. Mirror (external).
n. Nerve.
p. Pigment.
ph. Photogenic cells.
ph'. Photogenic cells of accessory organ.
r. Reflector (internal).

vessels and nerves. These, then, are the essential parts of the apparatus, though even here differences obtain: for example, in *Thaumatolampas* the cells are polyhedral, highly refractile, and clearly defined, with spherical nuclei and distinct nucleoli. In *Chiroteuthopsis* the cells are few and large, and partially fuse one with another. In *Pterygioteuthis* the fusion has proceeded so far that the cell-boundaries are no longer recognisable, and there is present a finely granular mass in which numerous nuclei of varying size may be distinguished. In other cases the cells branch out into fibres and form a reticulate structure (*Calliteuthis*). In rare cases, as, for instance, the tentacular organ of *Thaumatolampas*, above described

this essential part constitutes the whole organ; but generally other structures are superadded, such as a pigment coat, reflector ('tapetum' of Chun), lens, and diaphragm, as has been mentioned in the complex organs just described.

Numerous interesting questions at once suggest themselves in regard to these structures, and it is very disappointing to admit that in regard to almost every one the answer is a confession of ignorance.

The first inquiry is, What is the origin of these organs, and from what primitive structures are they evolved? Here it is possible to say but little; there is no instance in which the development of these organs in the embryo has as yet been studied. A larva, believed to be that of *Histioteuthis,* came into my hands a short time ago, and full of hope I had a portion of the mantle cut into sections, but with no result whatever; there was nothing which I could interpret as the rudiment of such an organ.

Those organs occur in so many and such scattered families that it seems clear they must be polyphyletic. Furthermore, even in one and the same species the different organs are not all constructed on the same plan. In *Abraliopsis,* for example, the pallial organs are quite different from the ocular; but the most striking example of this sort of complexity is found in the remarkable *Thaumatolampas* (5), which has altogether twenty-two organs constructed on no fewer than ten different principles. It seems difficult in such a case to resist the conclusion that these organs have been separately evolved at different times, and perhaps from different origins, during the phylogenetic history of the species.

This variety in the structure of these organs naturally suggests the query, Do these differently designed lamps give out different kinds of light? Here we have the observation of Professor Chun (4) on board the 'Valdivia' to guide us, according to which in the living animal the middle ocular organ shines with an ultramarine light, whilst the middle of the five ventral organs is sky-blue and the anal organs are ruby-red. It may also be observed that even in preserved specimens, when examined in a strong light, the different organs seem to shine with different colours, although there is under such conditions no actual emission of light. Furthermore, in some forms (e.g., *Calliteuthis*) there are chromatophores in the superficial layers of the integument over the luminous organs, through which the light admitted must pass. A somewhat similar arrangement obtains in the curious structures in *Chiroteuthis,* which were regarded by Joubin (20) at the time of their discovery as 'thermoscopic eyes,' but which are, I think rightly, in the present state of our knowledge considered to be a special kind of luminous organ. In these instances the function of the superficial chromatophores may be to colour the light which passes through them.

The question of the utility of these variously coloured lights to the creature possessing them admits of an answer which is, at all events, extremely plausible. It was suggested in the case of deep-sea fishes by Brauer, and has been adopted by Chun in reference to the Cephalopoda. They serve as recognition marks by which the various species can identify their fellows; just as certain colour patches in the plumage of birds enable them to find their mates, so in the darkness of the ocean abysses do these fairy lamps serve their possessors. Another and perhaps even more obvious utility is suggested by the general distribution of these organs. It has above been pointed out that they are, almost without exception, on the ventral aspect of the body, that is, the inferior surface in the position in which the animal habitually swims. It must happen, therefore, that when the creature is moving over the floor of the ocean in the quest for food, this must be illuminated by its lamps, and the advantage of a series of searchlights playing over the ground will be at once apparent.

Finally we have the question, How is the light produced? To this we can only say that this is an instance of the transformation of one kind of energy into another. We are quite familiar with the production of heat in the animal body by the processes of oxidation which go on in it; we are also familiar with the production of kinetic energy when a muscle contracts under a nervous stimulus; and we are also aware that electric discharges are produced under similar conditions in certain organs of the Torpedo and other fish. The production of light is

a phenomenon of the same kind. When we can explain how stimulation applied to a nerve causes contraction in a muscle, then, and not till then (so far as I can see), shall we be within reasonable distance of explaining the action of these living lamps.

One point is worthy of notice which has been ascertained, not by experiments on the Cephalopoda, but on other animals, namely, the remarkable economy of this illuminant. A perfectly infinitesimal proportion of the energy expended is wasted on the production of heat. From this point of view animal phosphorescence puts to shame our most modern devices. Whether we shall ever be able to rival Nature in this respect remains to be seen.

We have thus shown how rapid has been the growth of our knowledge regarding the distribution and structure of these fascinating organs, and yet how little we have learned of the mode of their operation, and we end, as all scientific inquiries end when pursued far enough, with a confession of ignorance.

What I have ventured to lay before you are a few of the fruits of the little garden plot in whose culture I have been privileged to take a humble share. If it has appeared to you that the labour spent upon their production by a few enthusiastic workers has been well expended; if they show that in this, as in any other group of animals, the study of small details conscientiously carried out leads to problems of the deepest interest, my object in the preparation of this Address will have been fully achieved.

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Joint Meeting with Sections C, E, and K.

The Preservation of Natural Monuments. By Professor CONWENTZ.

FRIDAY, AUGUST 2.

The following Papers and Reports were read :—

1. *Experiments on Seasonally Dimorphic Forms of African Lepidoptera.* *By* F. A. Dixey, *M.A., M.D.*

It is now well known that the phenomenon of seasonal dimorphism is of common occurrence in tropical and subtropical lepidoptera. In those species that produce several broods in the course of the year it is often found that the successive broods differ widely in appearance according to the meteorological conditions prevailing during their immature stages. The contrast between such seasonal phases becomes especially marked in the case of forms inhabiting regions where there is a sharp distinction between the periods of rain and of dry weather.

The succession of these distinct phases is not determined by a regular principle of alternation; for in the instance of quickly breeding forms a series of successive generations may follow one another during the same 'wet' or 'dry' season, all the generations being of the same type, and varying in number according to the duration of the 'wet' or 'dry' conditions in any particular year. But no sooner do the meteorological conditions change than the next emerging brood of the same species shows a corresponding alteration, often sudden, but sometimes so gradual that it appears to take two or more transitional stages to bring the insect up to the full development of the new seasonal phase. This latter phenomenon is especially well marked in the genus *Byblia.*

Experiments have been tried with a view to ascertaining the particular stimulus or combination of stimuli which causes the butterfly to assume its special seasonal form at the appropriate time. In the classical instance of the European *Araschnia prorsa-levana* it was found by Dorfmeister, Weismann, Merrifield, and others that pupæ which left to themselves would have produced the 'summer' form *prorsa,* will if refrigerated give rise to a phase more or less closely resembling the 'spring' form *levana.*

Similar trials have been made with tropical and subtropical species, but until recently with somewhat inconclusive results. Mr. G. A. K. Marshall, however, working at Salisbury in Mashonaland, has now succeeded in showing that by artificially varying the conditions to which the butterflies are exposed in their immature stages it is possible to bring about in the midst of one season the emergence of a form which under natural conditions would only have been produced in the other.

Mr. Marshall has further demonstrated by experiment that the period of growth during which the butterfly is susceptible to climatic influences varies in different species, the critical stage being in some cases confined to the larval, in others to the pupal condition. He has also shown in one instance (that of *Belenois severina*) that the effect of moisture combined with heat differs entirely from the effect of the former factor alone.

Some of the actual results of the experiments referred to are exhibited, the specimens shown belonging to the genera *Teracolus* (*T. achine* Cram. and *T. omphale* Godt.) and *Belenois* (*B. severina* Cram.). The exhibit also includes specimens of other groups to illustrate the general principle.

2. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 346.

3. *Functions of the Spiracle in Sharks and Rays.* *By* A. D. Darbishire.

4. *Report on the Occupation of a Table at the Zoological Station, Naples.*—See Reports, p. 346.

5. *Report on the 'Index Animalium.'*—See Reports, p. 347.

6. *Report on Experiments on the Development of the Frog.* See Reports, p. 347.

7. *Report on Colour Physiology in Animals.* See Reports, p. 349.

8. *Interim Report on the Effects of Sera and Antisera on the Development of the Sexual Cells.*—See Reports, p. 350.

9. *Interim Report on Zoology Organisation.*—See Reports, p. 350.

10. *Seventeenth Report on the Zoology of the Sandwich Islands.*

11. *Joint Discussion with Section K on the Physical Basis of Inheritance. Opened by* Professor SYDNEY J. HICKSON, *F.R.S.*

The theory that the chromosomes of the ovum and spermatozoon constitute the physical basis of hereditary characters appears to be accepted by many biologists, and there is a danger that it will become incorporated among the dogmas of our science unless opportunities are taken for ample discussion of the known facts of cytology that tell both against and in favour of the theory.

The principal piece of evidence that is quoted in favour of the hypothesis is the experiment of Boveri (1889), which demonstrated that an enucleate ovum of one species fertilised by a spermatozoon of another species produced a larva with purely paternal characters. As confirmatory evidence of the theory there have been quoted (1) the constancy in the number of the chromosomes in the somatic cells, (2) the reduction to one half of the normal number of chromosomes in the sexual cells, (3) the presence of similar heterogeneous chromosomes in the sexual cells of certain arthropods and their mutual relationships.

If the theory is true it appears to be necessary to believe in the individuality of the chromosomes, that is to say, that the chromosomes seen at the poles of the spindle at the close of mitosis are individually the same chromosomes as those that are seen on the equator of the spindle at the next mitosis.

If the theory is true it follows that the cytoplasm of the ovum and spermatozoon plays no part in the transmission of hereditary characters.

The principal difficulties at present in the way of accepting the theory are briefly as follows: Experiments in merogony have shown that an enucleate egg fertilised by a spermatozoon of another species of animal does not always give rise to a larva with purely paternal characters. The evidence that in some animals the individuality of the chromosomes is not maintained, particularly in certain rhizopoda and infusoria among Protozoa and certain Cœlentera, is convincing. In the tissues of most animals and plants there is no direct evidence that the individuality of the chromosomes is maintained between successive mitoses.

If it is true that the cytoplasm of conjugating cells is not concerned with the transmission of hereditary characters, it is difficult to account for (*a*) the long

duration of the period of conjugation in Infusoria (Heterokaryota), (*b*) the cases of fertilised enucleate eggs that produce larvæ with maternal characters.

The evidence derived from the development of parthenogenetic eggs is contradictory, but does not, on the whole, support the theory that the chromosomes are the only physical basis of hereditary characters.

12. *Pycnogonida (Sea Spiders).* *By* T. V. Hodgson.

13. *On some Points in the Development of* Ophiothria fragilis. *By* Professor E. W. MacBride, *M.A.*, *F.R.S.*

Ophiothria fragilis is a common British ophiurid found in swarms near Plymouth, where the material for the researches recorded in this paper was obtained. The eggs are small and opaque, and cultures were obtained both by fertilising the egg artificially and by allowing males and females to spawn naturally. In addition a large quantity of material was obtained from the plankton, and by the use of all three sources it was found possible to make a complete study of the development, a full account of which will shortly be published in the 'Quarterly Journal for Microscopical Science.'

When the eggs are fertilised artificially segmentation results in the formation of a *morula*. An invagination of the outer layer of this follows, and it then transpires that the interior cells are precociously formed mesenchyme. The invagination of the outer layer takes place in such a way that a solid tongue of cells is left projecting into the archenteron. The cœlom then appears as a single vesicle at the apex of the gut, whilst the larva assumes a triangular shape, the two lateral points being the first rudiments of the larval arms. The primary mesenchyme migrates into these, and forms the basis of the calcareous rods which support the arms.

When the eggs are fertilised naturally segmentation results in the formation of a thick-walled blastula; then a regular invagination follows without the formation of any tongue of cells. At the opposite pole of the larva from the blastopore a great crest of vacuolated cells is formed, which is absent in larvæ resulting from eggs fertilised artificially. The larva now assumes a triangular form, the cœlom appears at the apex of the archenteron as a bilobed vesicle, and the crest slowly diminishes in size.

The difference between these two kinds of development is to be attributed to the fact that the artificially fertilised eggs were not quite ripe, and hence were of different chemical constitution from ripe eggs. In certain features of their development the artificially fertilised eggs resemble the eggs of *Ophiura brevis*, a species with shortened development. Are mutations due to slight chemical differences in eggs at the moment of fertilisation?

In the subsequent history of the larva the single cœlomic vesicle divides into right and left halves. Of these, first the left and then the right divide into anterior and posterior portions. Somewhat later from the anterior portions of both right and left sides are budded off sacs. That on the left side becomes five-lobed, and is the rudiment of the water-vascular system; it subsequently grows round the œsophagus. That on the right side, the equivalent of the dorsal sac of the Echinopluteus larva and of the Bipinnaria, ordinarily remains small, but sometimes assumes a five-lobed form, showing that it is a rudimentary fellow of the water-vascular system. The larva of *Ophiothria fragilis* affords final and convincing proof that the echinoderm larva possesses three somites, the middle one of which becomes on the left the water-vascular system.

14. *The Rise and Recognition of Economic Biology.* *By* Walter E. Collinge.

MONDAY, AUGUST 5.

The following Papers were read:—

1. *Sex in the Crustacea, with special reference to the Origin and Nature of Hermaphroditism.* *By* GEOFFREY SMITH, *M.A.*

The great majority of Crustacea have the sexes separate, and this is also true of the phylum Arthropoda as a whole. There are, however, two large groups of Crustacea, the Cirripedia and the parasitic Isopoda, which are for the most part hermaphrodite; and since these two isolated groups stand alone in this respect among allied groups, we may be certain that the hermaphroditism has been secondarily acquired from some diœcious ancestor. It is therefore interesting to inquire under what conditions hermaphroditism may arise in a diœcious species.

The most searching analysis of hermaphroditism is afforded by the phenomena of parasitic castration, which was first discovered by Giard,[1] and has been subsequently studied by the author[2] and Potts.[3] The result of these studies has been to show that a number of animals belonging to widely diversified phyla, but especially the Crustacea, when attacked by various parasites, undergo an alteration in their sexual nature of such a kind that at first the gonad in both sexes degenerates to a greater or less extent; secondly, the males assume in varying degrees the secondary sexual characters proper to the female, while the female, without assuming any male character, suffers a certain amount of degeneration in the secondary characters proper to the female. Finally, either on recovery from the parasite or else during the degenerative process, the male may develop ova in its testes, and these ova may grow to a very large size, lying side by side with mature spermatozoa. The females, on the other hand, just as they never develop male secondary characters, also never produce spermatozoa in their ovaries. These results apply especially to the effects of the parasitic Rhizocephala upon the crabs which they infect.

We see then, first, that hermaphroditism in the Crustacea can be called forth in its completion by an external cause acting upon a sexually differentiated animal, and secondly, that it can only be called forth in this way in the male sex, not in the female.

What is the nature of this cause? If we look for parallel cases, we find in the Crustacea that a partial temporary hermaphroditism is assumed by the males of certain forms (especially crayfishes, spider-crabs, and sandhoppers of the genus Orchestia) at particular seasons, when a period of growth as opposed to one of reproduction is being initiated. It appears that the males, in order to increase their vegetative activity, have to suppress the male part of their organisation and call into play the female part. This also gives an explanation of the behaviour of males under the influence of parasites; for in order to cope with the drain on the system caused by the parasite they have to increase their vegetative activity, and this they do by suppressing their male organisations and calling into activity the female, which they possess in a latent state.

These facts point to an extremely close connection between sex and metabolism in general.

The conclusion that hermaphroditism is a property of the male sex developed in response to altered conditions of metabolism can be applied to the origin and nature of the hermaphroditism found normally in the Cirripedes and parasitic Isopoda. Both these groups lead a sessile, inactive existence when adult, and in them the passive vegetative functions are developed to a high degree.

In the parasitic Isopoda all the individuals are at first males, when they live a larval free swimming existence; on settling down to the parasitic existence they develop the female part of their organisation. The Cirripedes exhibit many interesting variations; but the presence in some of them of males which may

[1] *Bull. Sc. Dép. Nord*, 10, 11. [2] Naples Monograph, *Rhizocephala.* [3] *Q.J.M.S.*, vol. 1.

degenerate completely even in the larval state, and a number of other facts, point to their having passed through a condition similar to that of the parasitic Isopods, in which all the individuals are primarily males and subsequently females.

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2. *Exhibition of Photographs of a Living Okapi.* *By* Sir E. Ray Lankester, *K.C.B.*, *F.R.S.*

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3. *The Pendulation Theory in relation to Geographical Distribution.* *By* Professor H. Simroth.

According to the pendulation theory, the earth not only performs its movements of rotation and revolution in a day and a year respectively, but also has a much slower swinging movement (pendulation) about an axis which corresponds with the longest diameter of the globe, and has its poles in Sumatra and Ecuador. These may be called the 'swing poles' of the earth, or the east pole and the west pole respectively. In this movement the north pole and the south pole swing to and fro along a meridian which passes through Behring's Strait and divides the Alps into an eastern and a western half corresponding nearly with the Valley of the Rhine: this may be called the 'swing' or 'pendulation' circle. The meridian passing through the east and west poles may be called the culmination circle, because each point of the earth in swinging towards the north reaches its most northerly position at the time when it crosses that circle.

During the Glacial epoch Europe approached the north pole; during the Cretaceous and Eocene periods it was in a tropical or sub-tropical position. In the Palæozoic period also Europe was in a polar phase, which in the Permian period brought about a more ancient Glacial epoch. In Secondary times Europe moved in the direction of the equator.

In consequence of the difference between the short and the long radii of the earth, Europe would emerge from the ocean when in the polar phase and be submerged under it during the equatorial phase, because the water, owing to the rotation of the earth, will always take the form of the geoid, whilst the hard crust will only take this form gradually and at a much later period. This explains the circular emergence and submergence of the solid land.

This pendulating movement furnishes the key to the solution of a large number of problems in the geographical distribution of organic beings both in present and past times. As the earth was once much hotter than it is now, and the crust was in a molten condition, we must go back for the origin of living beings to an old intertropical stock in Cambrian or pre-Cambrian times. These beings made their way out of the tropics and into a cooler climate in a perfectly mechanical manner, the movement always reaching its maximum on the swing circle. In this migration there were various possibilities. If the organism were capable of sustaining great variations of temperature (eurythermous), the northern boundary of its area would form a convex curve under the swing circle. If it were a stenothermous one, it would become extinct under this circle, and thus come to inhabit two separate areas symmetrically disposed with regard to the circle. If it were a plastic organism, it would become modified into a new variety or species. If the cooling were excessive, it would migrate into the water where the conditions of life are more uniform. The evolution of water animals might also take place in the opposite equatorial phase by mechanical submergence. The first of these methods has happened in the case of the Cetacea, the second in the higher marine Prosobranchs. The same process has taken place also in the more northern position, the organisms always moving sideways along the same parallel of latitude until they arrive at suitable conditions.

The earth is divided by the culmination circle into two hemispheres, a Pacific and an Atlanto-Indic. In the former the water prevails; in the latter Europe and Africa occupy the position of the 'swing circle.' The higher forms of animals and plants being those which inhabit the land, the Atlanto-Indic has taken the

greatest share in the evolution of living beings. The perfection of this process, however, depends upon the alternation of emergence and submergence. The outlines of Africa are too uniform for this process to be very effective, the irregular coast-line of Europe producing more striking effects in this direction. Therefore Europe (including Africa north of the Sahara) has always been the centre of organic evolution. All organisms have been dispersed hence in the manner just described. They have migrated eastwards and westwards or south-westwards to the west pole, or even further, till they arrived at a suitable environment. Those groups which are not now confined to a single locality inhabit places which are symmetrical with respect to the 'swing circle,' or points which have a similar relation to the swing poles, *e.g.*, California and Japan, Chili and New Zealand or East Australia, Spain and South Russia, &c. In many cases the mode of dispersal is proved by the organism still inhabiting intermediate stations, or its remains being found there in a fossil condition. Numerous instances of this might be mentioned, the human race furnishing one of them.

Not only is the geographical distribution of creatures now living explained by the pendulation theory, but also the geological periods themselves. A geological period is not a definite epoch extending at the same time all over the earth, but it is a wave originating in Europe and spreading over the globe along the lines indicated above.

If the great epochs correspond with the great pendulation movements, then the shorter periods (*e.g.*, the interglacial periods) are to be explained by its being complicated with other movements. The north pole of the earth moves round in a circle in a period of about twenty-six thousand years; hence the pendulation cannot proceed in direct lines, but must have a screw-like form, the straight line along the 'swing circle' being the result. The smaller alternating secondary movements give rise to the shorter periods.

The elevation of the mountains is the consequence of their passing into a polar phase. The land rises more and more above sea-level as it approaches the north pole, but eventually it also succumbs to the centrifugal force of the earth's rotation, breaks down, and becomes faulted. The greatest development of this process takes place in the latitude of 45°; the lines of elevation are those along which the organisms spread, and they also mark out the places in which earthquakes occur.

The continent of Africa would seem to be the primary cause of this pendulation. Without Africa the new world and the old world would present a somewhat symmetrical appearance, and the process of pendulation is gradually bringing this to perfection. It has almost succeeded in the Pacific hemisphere, but in the Atlanto-Indic hemisphere the continent of Africa forms an obstacle which cannot be removed by denudation or other causes. Africa seems to be an old moon which has fallen upon the earth in a direction from the south-west.

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4. *On the Systematic Position of* Polypterus. *By* E. S. Goodrich, *F.R.S.*

Polypterus and *Calamoichthys*, from the rivers of tropical Africa, are two closely allied genera which together form the order *Polypterini*.

That they are forms of very exceptional interest, that they occupy a very isolated position in the classification of fish, there can be no doubt. They are distinguished from all living fish by many important anatomical characters and have no close living relatives. One need only mention the presence of rhomboid ganoid scales, of paired gular plates, of a persistent spiracular gill-slit, of true clavicles, of a ventral bilobed air-bladder, and a straight tail, forming a combination unknown in any other order.

Owing to their lobate pectoral fins, paired gulars, rhomboid scales, and outwardly diphycercal tail, and to a considerable resemblance in the disposition of the roofing cranial bones, Huxley placed the *Polypterini* in the group *Crossopterygii* in his famous paper on the Classification of Devonian Fishes.[1] *Polypterus*

[1] 'The Systematic Arrangement of the Fishes of the Devonian Epoch,' *Mem. Geol. Surv.*, 1861.

was thus associated with such extinct forms as *Osteolepis*, *Glyptopomus*, and *Holoptychius*, a position in which it has been left by subsequent writers.

But comparing *Polypterus* with these fossil fish, we find that the resemblance is by no means close. The similarity in the disposition of the surface bones of the skull is only general, and such as may be found in most primitive teleostomes. The scales, though like those of osteolepids in outward appearance, are really of very different structure: the latter are covered with an outer layer of cosmine, and do not grow by the addition of complete layers of bone below and ganoine above. The scales of *Polypterus*, on the other hand, are of the true ganoid type, resembling closely those of the palæoniscids, and grow like these by the addition of concentric layers of bone and ganoine.

That the tail is not truly diphycercal is shown by its internal structure. A heterocercal fin has a well-developed ventral or hypochordal lobe, which is always supported by direct prolongations of the hæmal arches, whereas other median fins have always separate distal radial elements. Now in a diphycercal caudal fin, such as the dipnoan or crossopterygian, both the ventral and the dorsal lobes have such separate radials jointed on to the vertebral arches. If we examine the tail of *Polypterus* we find that the notochord does not nearly reach the extremity; that its extreme end is, in the young at all events, slightly twisted upwards (as shown by Budgett); and, lastly, that the hypochordal lobe is supported by direct prolongations of the hæmal arches (as described long ago by Kölliker). The evidence clearly points to the caudal fin of *Polypterus* being of a modified heterocercal type.

Coming now to the gular plates, *Polypterus* alone among living fish has a large ventral pair. Such plates are found among early extinct *Dipnoi* and *Crossopterygii*: in these the large pair appears not to belong to the lateral series, but occupies the ventral region between them. In the *Actinopterygii* there may occur a median ventral plate with two lateral series as well (*Amia*). Now two of the anterior paired plates may be more or less enlarged (*Palæoniscidæ*); and it therefore becomes a question whether, after all, the paired plates of *Polypterus* are not the homologues of these plates of the *Actinopterygii*, instead of the homologues of the more median plates of the *Crossopterygii*. This suggestion is supported by the discovery of a median gular fold between the plates of *Polypterus*.

Already some years ago [1] it was pointed out that the skeleton of the pelvic fin and girdle of *Polypterus* is much more actinopterygian than crossopterygian in structure. With regard to the more important pectoral fins, the resemblance to the lobate fins of the *Crossopterygii* has been shown by Budgett [2] to be superficial only. For in these extinct forms the endoskeleton possessed a jointed well-defined axis, with probably a series of radials on each side of it; while in *Polypterus* the radials are grouped together in fan like arrangement, with an ill-defined posterior axis, much as in the lower *Actinopterygii*.

The evidence in favour of a close affinity with the extinct *Crossopterygii* is therefore neither convincing nor even strong. On the other hand, the theory that *Polypterus* is nearer to the *Actinopterygii* is supported by a comparison of the structure of the scales and of the fins, by the presence of large solid otoliths in the ear and of double dorsal nostrils on each side of the snout. The study of the anatomy of the soft organs, though of little use in a comparison with fossils, on the whole strengthens the theory; the brain, the alimentary canal with its pyloric cæcum, the kidneys and testis, the separate anus and urino-genital aperture, are all consistent with the view that *Polypterus* is related to the *Actinopterygii*.

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5. *The Thickness of the Skull in Mammalia.* *By* Professor RICHARD J. ANDERSON, *M.A., M.D.*

Light shines through the orbital roofs in the young chimpanzee. The coronal and sagittal regions are opaque.

The occipital fossæ, and roof and sides of the skull are translucent in the ox.

[1] *Quart. Jour. Micr. Sci.*, vol. xlv. 1901. [2] *Trans. Zool. Soc.*, vol. xvi. 1903.

The kangaroo and camel each have translucent roof and sides of skull (except in region of horns), so has the seal. The parietal in part is translucent in both manattee and dugong. The upper surface of the skull in dogs is not so translucent as the sides. The dolphin's skull is opaque above and translucent behind, and at the central part of sides. The proliferation of the bone cells along muscle attached appears to co-exist with the diminution of the bone under brain and muscle pressure. The bone cells, like leucocytes, desire to avoid the centres of turbulent activity.

The skull of the porcupine is translucent over the frontal and parietal; the capybara has a skull that is translucent on each side of the middle line in front of the roof, and also at the posterior part of the roof, where the translucency is strictly limited to the upper surface. It is sometimes stated that the portions of the skull covered by muscle (or 'protected') are thin. The suggestion is that the skull is strengthened where most exposed. It seems better to refer the thinning to the pressure of the muscle mass, brain, or organ. The ridges are due to the accumulation of bone-forming tissue at the points of origin and insertion of the muscles in question. The skull does not appear to lose, but to gain, in strength by the groining (J. Hunter and Holden). The osteoblasts, like leucocytes, seem to avoid the places where thrills or shocks are most common. The former have greatest freedom outside the active centres, as the latter in the least disturbed nooks contribute to the formation of fibrin.

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6. *Joint Discussion with Sections K and L on the Teaching of Biology in Schools. Opened by* Oswald H. Latter.

The right of biology to rank as a subject in general education is now generally conceded and its merits recognised. As a training in experiment, in precision, and in exact reasoning it perhaps has not the advantages of physics and chemistry; but in quickening the powers of observation it is unsurpassed by any of the sciences. Moreover, it deals with phenomena which perforce must come before every man in the daily concerns of occupation and leisure, and on which indeed his very existence depends. The laboratory and all its paraphernalia are not always necessary for its pursuit.

Of the two biological subjects, zoology and botany, the former will receive my attention, rather at the request of those responsible for summoning this conference of Sections than because I attach superior importance to the subject in which I chance myself to have been trained. Twenty years' experience as a teacher has convinced me that were I constrained to teach only one biological subject my choice would fall upon botany for purposes of general education.

At what age, then, (1) should the study of zoology begin? (2) Along what lines should it be pursued? And what relation should this subject bear to the other sciences which find place in curricula? (3) How far may we proceed into zoological principles and philosophy? These questions apply to class teaching and not to those special divisions—elementary technical sets—which are for the most part composed of embryo medical students.

(1) Living animals present great attractions to and deeply interest the minds of quite young children. Thus there is the ample justification of Nature's own authority for a very early commencement. In the preparatory school and lower forms of public schools the standard indicated by the term 'nature-study' is undoubtedly the very best form of science training. When applied to animal-study this resolves itself into observation of habits and life-histories, methods of locomotion, of feeding, and perhaps of breathing; noting of the external form and its special adaptations to the circumstances of life. It is essential that each pupil shall learn as the result of direct personal observation; mere reading and lectures, except that they may arouse some interest, are of no value. Assuming, then, that each pupil is provided with living specimens, the guidance of the teacher is needed to direct the attention to the important features. And here it is important to avoid doing too much. The guidance afforded should consist of

a series of questions which can be answered only as the result of examination of the object. To tell the pupils that such and such is the case and then request them to verify the statement is destructive alike of interest and of the beneficial results which are the aim of all science teaching. But it is quite legitimate, after all that is possible has been found out, to impart a little additional information by way of explanation of facts observed. For example, supposing that the respiratory movements of a frog be under notice, we may ask the class to describe the movements of the throat, nostrils, ear-drum, and flanks, to note the condition of the mouth, to time the frequency of the various movements and describe their relation one to another; but we shall not be wrong subsequently by the aid of a model and by blackboard diagrams to get the class to reason out, with a little assistance, how the air is forced into the lungs by the compression exerted by the floor of the mouth cavity. (2) Both in the nature-study and in all later stages of *class*-teaching the work should deal largely, indeed exclusively, with animals that are common. Insects, earthworms, mussels, snails, spiders, lobsters (crayfish), crabs, centipedes, fish, frogs and toads, newts, lizards and snakes, birds, and the domestic and more familiar British mammals, form an ample stock of material from which to select examples. It is impossible to treat of all, nor is it desirable to attempt to make zoologists of everybody. Hence the 'type-method,' with its underlying idea of evolution, is not suitable for purposes of general education. What we aim at is rather that everyone shall gain an intelligent interest and sympathy with the lower animals, and shall understand to some extent how these live and move and have their being, their importance to man in his industries and otherwise, and, since man is an animal, something of the structure and healthy working of the human body. With older and cleverer pupils pure nature-study methods become insufficient. As the mind matures it must have more solid matter to digest. In our enthusiasm for a new method of teaching we are all rather apt to supply an infantile diet to minds that are not thereby strengthened. The first mammal that was evolved in Nature's workshop probably did not continue to suckle her young after they acquired teeth fit for chewing solid food. We may therefore in our secondary stages proceed to ask more about the 'how' and the 'why' of animal phenomena; in other words, to begin physiology. But this of necessity demands at least some training in physics and chemistry; and I am strongly in favour of interpolating a year devoted to the elements of these subjects before proceeding further with zoology proper. On the other hand I would not separate function and structure into water-tight compartments, but as far as possible take them together. A very large portion of the physiology should be human, even when we are dealing with invertebrate animals. A comparatively slight acquaintance with physical and chemical methods will enable pupils to find out many of the properties of bread, milk, eggs, butter, and other foodstuffs; saliva is readily accessible for experiments on digestive processes, and pepsin and hydrochloric acid can be purchased without much difficulty. Similarly the essential features in respiration can be ascertained with the simplest of apparatus; and when these are taken in conjunction with experiments on the combustion of foodstuffs, part at any rate of the metabolic processes becomes intelligible. Pupils are always deeply interested in human physiology; indeed I know no subject which holds the attention of classes more firmly; and incidentally it may be remarked that the opportunity arises of imparting many a valuable lesson in all aspects of hygiene. A very real difficulty is the question of laboratory work and dissection. In the short space of time usually allotted to science, dissection is almost impossible, even if there be laboratory accommodation for the purpose. Nevertheless a good deal of this can be done with some animals, *e.g.*, insects and crustaceans, if one rests content with externals and then supplements deficiencies by museum preparations, microscope slides thrown by the electric lantern on the screen, and so on. (3) It would be valuable to obtain an expression of opinion from teachers present on the questions of introducing the theory of evolution and principles of classification, and, if these are to be introduced, whether it is best to begin with the unicellular animal and work upwards, or to adopt the reverse course. My own feeling is that this part, the most interest-

ing to the trained zoologist, is beyond the grasp of any but one's best class. The number of animals with which it is possible to deal is but few, and though it is clear enough that there is increasing complexity of structure and increasing differentiation of function among the organs, yet the premisses are not sufficient to warrant any conclusion that the higher has been evolved from the lower, nor to bring out the doctrines of homology. There are two natural opportunities of introducing the evolutionary aspect in these general courses. One occurs in studying the development of such animals as the frog and freshwater snail, where it is possible to see the unicellular ovum give rise to the multicellular adult, and the fish tadpole to the amphibian frog. The other can be combined with the principles of classification and homologies, as exemplified in the study of a series of closely allied animals, such as can easily be obtained among the crustaceans or insects, or, if more convenient, in the skeletons of vertebrate animals. The typical animals usually employed in university courses stand too far apart and require more supplemental lecturing than is advisable in a school course, which has not as its object a knowledge of the various styles of animal architecture. Lastly, a word of defence against certain opponents is necessary. It is by some maintained that anatomy and physiology are 'nasty,' and even indecent, and not fit subjects of education '*virginibus puerisque.*' To come straight to the main point, it is the processes of reproduction to which objection is made. It is even urged that zoology may be taught if this part of the subject be left out. There is no more mischievous suggestion. Are we to do all we can to encourage the study of animal life and then deny all information and guidance on phenomena which are bound to come under observation, as though these were something unholy and unclean? Curiosity on these matters is natural and inevitable, and it is far better, it is best, that this legitimate curiosity should be satisfied and instructed in a clean, wholesome, and scientific way than by any other means. It is only so that a reverent respect for the whole body, whether of brute or man, can be gained. *Puris pura omnia.*

TUESDAY, AUGUST 6.

The following Papers were read:—

1. *Note on the Structure of the Larva of* Lanice conchilega. *By* Rev. G. A. Elrington, *D.Sc.*

The larva of the polychœte worm *Lanice conchilega* passes in the first period of its life through a stage in which it is pelagic, and inhabits a transparent tube. The material of which this tube is composed is to a great extent secreted by a large glandular organ situated in the anterior region of the body, on the dorsal side of the œsophagus, and having an external opening on the dorsal surface of the animal in the median line.

The gland in question consists of a cluster of large pear-shaped cells, the thin ends of which converge to form the orifice of the gland. Sections of the larva, including the tube, were stained with Delafield's hæmatoxylin and blue carmine, and it was found that both the tube and the cells were stained a deep purple; at the same time the cytoplasm of the cells was clearly differentiated from the rest of the cell contents by the light-blue colour imparted to it by the blue carmine. In a similar manner, toluidin-blue and safranin were found to stain the tube and the gland alike.

A slightly different result was obtained by using methylene-blue and alum carmine. In this case the secretion of the gland was stained blue; the tube, however, was not acted upon, except by the carmine. These results point to the conclusion that the gland plays some part in secreting the tube. This view is further borne out by the fact that the gland is a transitory structure, persisting as long as the larva retains its transparent tube. No trace of the gland could be

found in sections of a young lanice which had just commenced to build its sandy tube, and it is, moreover, not to be found in the adult worm.

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2. *Demonstration of Skin Varieties of* Cricetus frumentarius *of Thuringia.* *By* Professor H. Simroth.

The hamster is a rodent a little larger than the guinea-pig, living in cornfields, where it digs holes under the ground. It carries in its cheek-pouches a quantity of corn, which it accumulates in a compartment of its hole as provision for the winter time. It propagates rapidly, and, being of a very quarrelsome nature, every individual lives by itself in its own hole. The damage caused is enormous, the amount of corn in a single hole sometimes reaching as much as a bushel. For this reason the animal is dug out and killed in the autumn by special hamster hunters, who profit by the corn and by the skin. To show the quantity of hamsters in one district, I may say that in a field in the district of Halberstadt more than ten thousand were killed in one year.

The headquarters are in the North of Germany, between the mountains of Thuringia and the Hartz, this being the northern limit. It spreads to Western Germany, where smaller numbers inhabit the neighbourhood of the Rhine River.

The hamster inhabited the same countries before the Diluvium period; it disappeared during the Glacial epoch, but subsequently immigrated from Russia. The pretty skin is used for the lining of fur coats, as many as two hundred specimens being used for a coat of large size. The colour of the animal is grey or reddish-grey, the under-side black. Both parts are separated by a more reddish part surrounding the body. At the side of the head and the breast it is interrupted by three white patches, so that the forepart of the body is vividly coloured.

Some years ago, during the hot summers, I heard that black specimens were seen in the warmest parts of Thuringia, some of which I received both alive and dead. These were demonstrated in the 'Naturf. Ges.' of Leipzig with the hope of getting more information. The skinners' attention was drawn to the subject; it was then possible to obtain more specimens.

The amount of the annual harvest of hamsters in Germany is about a million, three quarters being obtained in Thuringia and one quarter in Western Germany. From among the greater stock of 750,000 specimens were taken the different variations which I now put before you. I have discarded all irregularly variegated forms. You will see a surprising amount of variability. First, there are the normal forms; here one fact is of interest—namely, that in the young animal the black pigment was found in the cutis, later on only in the hair. The next change of colour is the disappearance of the red, and later that of the white patches. The upper side becomes grey or greyish brown, finally blackish, so that the whole animal becomes uniformly black. In another direction the ventral side becomes lighter, the upper side varying in the way previously mentioned. In one specimen it is reddish, with white patches; in others, greyish or ochreaceous. As a further variation the under-side becomes white, and finally there is a perfect white or albino form, and I have been told that this form is the rarest. However, I suppose that this is not the continuation of the former series, but a phenomenon by itself. Here we have a maximum of variations in a mammal. What is the significance of all this? Have we to do with atavistic forms, or with prospective ones? Or can we observe here the mere influence of climate? One of the forms appears to be identical with the Syrian *Cricetus auratus*.

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3. *Plankton Fishing off the Isle of Man.* *By* Professor W. A. Herdman, *F.R.S.*

During recent years a good deal of attention has been paid by naturalists in various parts of the world to the *quantitative* distribution of organisms in the sea. It is obvious that exact information in regard to such a matter may be of enormous

importance in connection with the fishing industries. Notable methods of work, and instruments for the purpose of capturing and measuring the organisms present, have been devised by some of the German investigators, and these methods will always be associated with the name of Professor Hensen, of Kiel, to whom very great credit is due for the ingenuity and scientific enthusiasm with which he has conducted the investigation. It is very important that any criticisms which are required should be brought forward before further researches have been made, and before further material has been accumulated, and that any imperfections or limitations in the methods employed should be recognised.

The Hensen methods are based upon the assumption that the distribution of the plankton, or minute floating organisms in the sea, is so uniform over wide areas under much the same conditions that total populations can be calculated from relatively very small samples. [Examples were given of several of the conclusions arrived at as the result of such calculations by Hensen and his fellow-workers. The correctness of these conclusions, it will be noticed, depends entirely upon the assumed uniformity of distribution and upon the adequacy of a small number of samples as representing the whole area. Some criticisms of the plankton methods have appeared which are based upon imperfections of the instruments, variations in the nets employed, and such matters. These imperfections can be obviated or allowed for; but I wish to bring before your attention a much more fundamental difficulty—namely, the marked irregularity or want of uniformity in the distribution of the organisms.

At the time, five years ago, when I served as a member of the Ichthyological Research Committee, I was much struck by the evidence obtained of irregularity in distribution of marine organisms, and of the inadequacy of small samples taken at considerable distances apart, either in time or space, and further observations since have confirmed this impression. It has been a matter of common observation amongst naturalists that many of the larger organisms, such as Copepoda, occur in swarms; and this not merely around our coasts and in the narrow seas, but also in the open ocean. *Trichodesmium*, again, is found in the Indian Ocean occurring in enormous profusion over narrow bands. At the last meeting of the Association Dr. Fowler gave some interesting results he had obtained in regard to irregularity of distribution in the open Atlantic. These and other results which have been obtained, I believe, are not yet published.

Convinced of the fundamental importance of such work, I spent the greater part of my last summer vacation in experimenting day after day with various plankton nets under similar and under varying conditions in a limited sea-area off Port Erin, in the Isle of Man, with results that were startling in their diversity. It was obvious that the plankton was at that time very unequally distributed over the depths, the localities, and the dates. It seemed clear that one net might encounter a swarm of some organism which a neighbouring net escaped, and that a sample taken on one day might be very different in quantity from a sample taken under the same conditions next day.

I stopped this series of observations on September 17. After a few days of wind a spell of quiet, calm weather followed, during which I took some townettings, both inside Port Erin Bay and outside, both in the day and at night, and all of these differed entirely in character from the gatherings of the previous weeks, being composed mainly of Chætoceros and other diatoms. When the weather broke again, at the end of September, another abrupt change took place, and gatherings taken at the beginning of October showed very few diatoms, but many Copepoda. It is evident that if any observer had been taking quarterly or even monthly samples of the plankton in that sea area, he would have obtained very different results, according to the exact date of his visit. On three successive weeks about the end of September he might have found evidence for as many different far-reaching views as to the composition of the plankton in that part of the Irish Sea. How it can be supposed that hauls taken miles apart and repeated only at intervals of months, or even weeks, can give any sure foundation for calculations as to the population of wide sea-areas I fail to see.

These conclusions need not lead us to be discouraged as to the ultimate success

of scientific methods in solving what may be called world-wide problems, but they suggest that it might be wise to secure by detailed local work a firm foundation upon which to build, and to ascertain more accurately the representative value of our samples before we base conclusions upon them.

I do not doubt that in limited, circumscribed areas of water, in the case of organisms that reproduce with great rapidity, the plankton becomes more uniformly disturbed, and a comparatively small number of samples may then be fairly representative of the whole. That is probably more or less the case with freshwater lakes; and I have noticed it in Port Erin Bay in the case of diatoms. In spring, and again in autumn, when suitable weather occurs, as it did last year at the end of September, the diatoms may increase enormously, and under such circumstances they seem to be very evenly spread over all parts and to pervade the water at all depths; but that is emphatically *not* the case with the Copepoda and other constituents of the plankton, and it was not the case even with the diatoms during the present spring.

With the view of testing plankton methods still further, at another time of year, I devoted a month this spring (March 28 to April 27) to a systematic exploration, from the S.V. 'Ladybird,' of the sea off Port Erin at the south-west corner of the Isle of Man. We worked on twenty-three days and obtained 276 samples, an average of twelve per day.

[Particulars were here given of the localities, the methods, and the nets used.]

All the gatherings obtained are now being worked up in detail, and the results will be published during next winter by Mr. Andrew Scott and myself.

One or two broad features of the collections made were obvious. In the earlier part of the time, up to about the middle of April, diatoms were abundant, and nearly all the gatherings had a greenish tinge. During that period the plants were more abundant in the bottom waters, and the animals at the surface. Day after day we found that the two closing vertical nets hauled up from twenty to ten fathoms were of a brownish-green colour, and contained (especially the Nansen) an abundant gathering of diatoms. The surface nets during this time contained more Copepoda. On April 15 and 19, however, when the change in plankton was taking place, the diatoms were found to be mainly on the surface and the Copepoda below. As an example of wide distribution I may cite April 10, when the nets gave consistent results all the afternoon at three localities north of Port Erin, the diatoms being in all cases more abundant at the bottom, and the Copepoda on the surface.

We were fortunate enough on one occasion to obtain incontrovertible evidence of the sharply defined nature of a shoal of organisms, forming an instructive example of how nets hauled under similar circumstances a short distance apart may give very different results. On the evening of April 1, at the 'alongshore' Station III., north of Port Erin, off the 'Cronk,' one mile out, I took six simultaneous gatherings in both surface and deeper waters. Two of the nets were the exactly similar surface tow-nets which I have called B and C. At half-time, as the result of a sudden thought, I hauled in B, emptied the contents into a jar, and promptly put the net out again. This half-gathering was of very ordinary character, containing a few Copepoda, some diatoms and some larvæ, but *no Crab Zœas*. At the end of the fifteen minutes, when all the nets were hauled on board, all the gatherings, including B, showed an extraordinary number of Crab Zœas, rendering the ends of the nets quite dark in colour. B was practically the same as C, although B had only been fishing for seven minutes. It was evident that at about half-time the nets had encountered a remarkable swarm of organisms which had multiplied several times the bulk of the catch, and had introduced a new animal in enormous numbers. Had it not been for the chance observation of the contents of B at half-time, it would naturally have been supposed that, as all the nets agreed in their evidence, the catches were fair samples of what the water contained over at least the area traversed, whereas we now know that the Zœas were confined to, at most, the latter half of the traverse, and may have been even more restricted. In these circumstances an observation made solely in the water traversed during the first seven minutes would have given a very different result from that

actually obtained; or, to put it another way, had two expeditions taken samples that evening at what might well be considered as the same station, but a few hundred yards apart, they might have arrived at very different conclusions as to the constitution of the plankton in that part of the ocean.

It is interesting to note that enormous numbers of *Oikopleura* 'houses' covered with diatoms were present in some of the gatherings during April, and that the abundance of the diatom *Thalassiosira Nordenskioldii* was phenomenal. We have some reason to think that there has been an exceptional flow of cold water from the north into the Irish Sea this spring, and that may account for the presence of this northern diatom which has not been found in our region before.

As an example of two surface-nets hauled together, which gave much the same quantity of plankton, but where the gatherings differed widely in their nature, I may give the details of April 13, when net A had 16 c.c, and net B 15·5 c.c., while the prevalent organisms were present in very different proportions in the two cases. [Table shown and details explained.]

The bearing of such observations as these upon some recent speculations as to the fish population of the sea, and even as to the amounts of food matters present in the waters of large areas, is obvious. Nothing in the economics of the sea could be more important than such speculations in regard to what I have proposed should be called the 'hylokinesis' of the ocean, if we could be certain that our conclusions are correct, or even that they are reasonably close approximations.

It is possible to obtain a great deal of interesting information in regard to the hylokinesis of the sea without attempting a numerical accuracy which is not yet attainable. The details of measurement of catches and of computation of organisms become useless, and the exact figures are non-significant if the hauls from which they are derived are not really comparable with one another, and the samples obtained are not adequately representative of Nature. If the stations are so far apart, and the dates are so distant, that the samples represent little more than themselves; if the observations are liable to be affected by any accidental factor which does not apply to the entire area, then the results may be so erroneous as to be useless—or worse than useless, since they may lead to deceptive conclusions.

My view in brief is (1) that we must investigate our methods before we attempt to investigate Nature on a large scale; (2) that we must find out much about our gatherings of organisms before we can consider them as adequate samples; and (3) that we must make an intensive study of small areas before we draw conclusions in regard to relatively large regions such as the North Sea or the Atlantic Ocean.

4. *Demonstration: Models of Protozoa.* *By* F. R. Rowley.

5. *Experiments on the Development of the Frog.* *By* Dr. J. W. Jenkinson.—See Reports, p. 347.

6. *The Classification of the* Haplosporidia. *By* H. B. Fantham, *B.Sc.*, *A.R.C.S.*

The *Haplosporidia* are parasitic Protozoa belonging to the class Sporozoa, and are a simple and probably primitive group near the base of the *Neosporidia*, for their reproduction takes place during the trophic phase.

The group *Haplosporidia* was founded by Caullery and Mesnil in 1899. As the name implies, the spores are simple—without polar capsules—and are uninucleate. The parasites occur in Rotifers, Annelids, Crustacea, and Chordates. The order, as originally defined by Caullery and Mesnil, has been extended recently to include a parasite, *Rhinosporidium kinealyi*, from the septum nasi of man,

and another, *Neurosporidium cephalodisci,* from the nervous system of *Cephalodiscus.*

A typical Haplosporidian begins its developmental cycle as a small, rounded, uninucleate cell, the spore, which may possess a spore-membrane but is undifferentiated internally. Growth takes place, coupled with an increase in the number of nuclei and a 'plasmodial' stage is reached. Later, this multinucleate trophozoite becomes divided into a number of ovoid or spherical 'pansporoblasts,' which give rise directly to one (as in *Bertramia*) or four simple spores (as in *Haplosporidium scolopli* and *H. marchouxi*). Such a spore, when set free, begins the life-cycle again.

In the case of *Rhinosporidium* and *Neurosporidium,* after the uninucleate spore has grown into a multinucleate trophozoite, the latter segments into uninucleate pansporoblasts, just as in the preceding cases. A difference then occurs, for each pansporoblast enlarges, its nucleus divides, and a 'spore-morula' is formed. We thus have a multinucleate pansporoblast or spore-morula, divided into many uninucleate sporoblasts (spore mother-cells), each of which, without further change, becomes a uninucleate spore.

On this account, Ridewood and Fantham have divided the *Haplosporidia* into two sections:—

(i) The *Polysporulea,* wherein the pansporoblast gives rise to a number of spores (nine or more)—e.g., *Rhinosporidium, Neurosporidium.*

(ii) The *Oligosporulea,* wherein the pansporoblasts give rise each to a few (four) spores, or only a single spore—e.g., *Haplosporidium, Bertramia, Cœlosporidium.*

Mesnil in a recent review has suggested that *Cœlosporidium,* from the body-cavity of the Cladoceran *Chydorus,* does not belong to the *Oligosporulea,* but merits a separate section (*Holosporulea*), since the whole organism becomes one 'spore.' But on referring to the published accounts of *Cœlosporidium* we find that this one spore, so-called, encysts and consists at first of many nuclei embedded in a mass of undivided protoplasm, but this protoplasmic mass *later* divides into numerous uninucleate small corpuscles, 2μ to 4μ long, which are gymnospores and are comparable to the true spores of the *Haplosporidia.* Probably the same will be found to occur in the cysts of *Caullerya mesnili* (Chatton), when its life-history is more completely known. In the present state of our knowledge the section *Holosporulea* seems hardly necessary.

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7. *The Movements of Spirochætes, as seen in* S. balbianii *and* S. anodontæ. *By* H. B. Fantham, *B.Sc., A.R.C.S.*

The Spirochætes are small unicellular organisms belonging to Haeckel's kingdom, *Protista.* Their general shape is that of a long, narrow, sinuous thread. *S. balbianii,* which occurs in the crystalline style and gut of the oyster, is from 50μ to 150μ long, and 2μ to 3μ broad. Its breadth is almost uniform, and its ends are rounded. *S. anodontæ,* from the crystalline style of *Anodonta cygnea* and *A. mutabilis,* is from 35μ to 50μ long, and $0{\cdot}7\mu$ to 1μ broad. The ends of *S. anodontæ* are pointed.

Both these organisms possess a structure characteristic of the genus *Spirochæta,* namely, an 'undulating' membrane, which is a spirally wound, lateral extension of the ectoplasmic periplast, and which is seen on careful staining to be longitudinally striated. These striations in the membrane may be called myonemes, and are contractile. The membrane also possesses a chromatic border. The nucleus is diffuse, and is in the form of a centrally placed spiral filament, with about sixty bars or rodlets of chromatin arranged on it at more or less regular intervals.

Previous accounts of the movements of these organisms are most meagre, and yet descriptions of such are very necessary to aid in determining between this genus, *Spirochæta,* and that of *Spirillum.* Such a study would be of the utmost

importance in the case of *S. obermeieri*, the pathogenic organism of relapsing fever. These Spirochætes move very rapidly, especially *S. anodontæ* with its pointed ends; indeed, so rapidly that it is almost impossible to analyse their motion when moving at full speed. In the case of slowly moving specimens, the organism moves forward while turning on its long axis. The motion appears to be resolvable into two components: (1) a vibratory motion of flexion of the body, mainly for progression; and (2) a spiral or corkscrew movement of the body as a whole, due to the winding of the membrane. The corkscrew motion is especially well seen in the case of *S. anodontæ*.

Waves can be observed passing down the thread-like body in a direction opposite to that in which the organism is progressing. Many waves, at least eight to ten, can be seen along the body of a rapidly moving form, while only some two to four appear in more slowly moving forms.

The movements occur in jerks. It is a matter of indifference which end of the body is directed forwards, for the parasite is capable of suddenly reversing its direction of movement and returning on its own path, even under normal conditions. Sometimes the organism appears suddenly from a deeper level of the liquid, and swims, or spirally bores its way, more or less vertically upwards, twisting itself into various peculiar shapes, such as Catherine wheels, described by Perrin.

Parasites are sometimes noticed anchored by one end to a detached epithelial cell. The free end of the parasite then executes violent lashing movements or intermittent flickers, or coils itself over and over.

These Spirochætes seem to move more rapidly than Trypanosomes, and with an added corkscrew motion. The body of a *Spirillum* is more rigid than that of a Spirochæte in motion, and flagella are present in the case of true Spirilla. But the so-called 'flagellate' ('ciliate') stages of Spirochætes, described by some authors, are merely myoneme fibrils split off from the membrane during its rupture, resulting from violent contortions or death struggles.

The membrane is the chief locomotor agent of the organism. The vibrations of the membrane itself are very slight, but its myonemes, by alternate contraction and relaxation, set up *transverse movements* in the surface of the body of the Spirochæte, and these movements are manifested as waves passing down the body in a direction opposite to that in which the organism progresses.

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8. *The Experimental Study of Heredity*. *By* R. C. PUNNETT.

9. *Demonstration of Inheritance of Eye-colour in School Children brought from Burbage, Hinckley*. *By* C. C. HURST.

Section E.—GEOGRAPHY.

President of the Section—George G. Chisholm, M.A., B.Sc.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

Geography and Commerce.

The subject which I have chosen for this Address is one that is very apt to raise questions that might lead to keen and even warm controversy. For the raising of such questions no occasion could be less suitable, and it will therefore be my endeavour to handle the subject in such a manner that burning questions may be altogether avoided. For that reason I propose to consider the relations of geography and commerce from an historical point of view, which at least gives one the opportunity of confining oneself to less debatable ground than is entered on when one ventures on prophecy, that 'most gratuitous form of error,' as it is styled by George Eliot. That I shall be able to keep wholly free from debatable matter is more than I can hope, but it is my intention to try to avoid it as much as possible by illustrating my subject chiefly by reference to the broad, familiar facts of commerce considered in the light of geographical and other implications that may be described as obvious—obvious, and yet perhaps not unimportant and not unworthy of having attention specially called to them; for, after all, the obvious is obvious only to those who are looking in the right direction and with the proper focus, not to those who are looking another way or far beyond what is immediately before them.

As the first of these obvious considerations I may point out that unquestionably the foundation of commerce is the mutual advantage to be derived from the exchange of commodities produced in different places. Geographical relations are therefore of necessity implied in commerce. But those who carry on commerce have always aimed at the greatest possible advantage to themselves, and the commerce that has always attracted the greatest attention is that which has resulted in the greatest additions to their wealth. Peculiar importance therefore belongs to the geographical relations between regions which under any given circumstances lead to the most profitable exchanges.

But before applying this consideration there is another point which must detain us a little. In speaking of wealth as I have just done I am aware that I have made use of a term which economists recognise as one requiring a great deal of exposition to prevent misunderstanding, and there is not the slightest doubt that in the history of commerce it has led to great misunderstanding, and therefore it is necessary, without entering upon an economic disquisition on the subject, to consider the meaning of the term 'wealth' sufficiently to indicate the way in which that misunderstanding has arisen. For this purpose it will be most convenient not to give one of the highly abstract definitions of wealth which a modern political economist will give us, but to go back to the more concrete considerations set forth by Adam Smith, who tells us that 'the wealth of a

country consists not in its gold and silver only, but in its lands, houses, and consumable goods of all different kinds.'[1] Now no definition of wealth is given by economists which excludes this last form of wealth, but the misunderstanding to which I refer arises from the fact that this form of wealth is apt to be overlooked. It may happen that a country or region produces a great abundance of consumable goods in proportion to its population, and hence from this point of view be entitled to be regarded as wealthy, and yet may not be a country or region that attracts much attention by its wealth. What has always attracted attention to wealth, and what has caused wealth to have an important effect in directing the main streams of commerce, and commerce to have an important effect, direct or indirect, on history, has been the accumulation of much wealth in few hands, so that a comparatively small number of people in a community have enjoyed, directly or indirectly, the command of a great deal of labour, have had the means of providing themselves with commodious and luxurious houses, with a variety of other comforts, luxuries, and splendours, and over and above that the means of so directing labour as to add still further to their wealth. Such conditions may exist where the great bulk of the population are extremely poor.

Now, it happens that wherever a great abundance of consumable commodities is produced on a relatively small area there is always in that area a greater or smaller number of individuals in whose hands much wealth is concentrated. It is for economists to explain how this comes about, or has come about, but it is a fact of the utmost importance for geographers to bear in mind in considering the relations of commerce and geography.

The existence of a relatively dense population may be due to different causes, such as a great abundance of agricultural products, the carrying on of mining or manufacturing industries, the concentration of the administration of a great dominion, or the pursuit of commerce itself. Where it is due to any cause but the production of great quantities of the necessaries of life foodstuffs must be imported in large quantities, and where the pursuit of manufactures is the cause, or one of the chief causes, then the importing of raw materials is entailed. Where these are most advantageously found there also much wealth is likely to be accumulated in few hands.

Further it is to be noted that where a comparatively small number have the command of much wealth there is sure to be a demand for things of such value that they can be bought only by the wealthy, things that are more or less rare, such as precious metals, jewels, gems, ivory, fine woods, ornamental skins and feathers, manufactured goods of rare materials or of fine quality, as well as, in many places and in most periods of history, slaves. Such trade is necessarily limited in amount, but puts great profits in the hands of those who carry it on with success, and for that reason attracts attention.

With this class of goods may be associated certain others that may be regarded as intermediate in position between those which are bought only by the wealthy and those which are not merely generally consumed but also very widely produced. Amongst these may be mentioned salt, the consumption of which is universal, but the production of which, away from the seaboards of the warmer latitudes, though in a sense widespread, is strictly confined to scattered spots. A more interesting example is that of spices, one of which, pepper, has from a remote period been very generally consumed, but in still smaller quantity than salt, and for that reason has been able to bear still higher transport costs. For ages these costs were very high, for various reasons, amongst which were risks both numerous and great, but the profits of those who were successful in the trade were proportionately high.

Peculiar importance in commercial geography is thereby given to the relations between the regions that yield or yielded spices and those in which they were consumed at a great distance from the place of origin, and one of the most important facts in human history is that for many hundreds of years an extremely valuable trade in these commodities was carried on between India and the

[1] *Wealth of Nations*, book iv., ch. i.

Mediterranean. Spices no doubt were less talked about, less prominent as symbols of wealth, than gems and jewels, fine woods and ivory, but they formed the basis of a larger trade, which was in the aggregate probably more profitable than that in the still more costly wares.

The geographical relations between India and the Mediterranean necessarily determined the routes followed by this traffic. These routes were singularly few. They were practically confined for the most part to minor variations in two main routes, one by way of the Red Sea, the other by the Persian Gulf. At more than one period of history, in very early times in the days of the splendour of Assyria and Babylonia, and again in the flourishing days of the Caliphs of Baghdad, the Persian Gulf route had a peculiar advantage in the existence of the large and rich populations that afforded an intermediate market; and another important fact in the relations of geography and commerce, one that has had vast effects on human history, is that the physical conditions of the area between the head of the Persian Gulf and the Mediterranean are and throughout human history have been such as to make the most convenient outlet of that route some point or points on that seaboard which in ancient times was known as Phœnicia. Between that seaboard and the Euphrates the desert is sufficiently narrowed to be most easily crossed. The most favoured outlets on this seaboard were not always the same. They varied in different circumstances, which gave a different geographical value now to one point, now to another. But on these variations, interesting and instructive as they are from a geographical point of view, there is no time to enter on this occasion, and it will be enough to call attention to a very interesting paper by the late Elisée Reclus entitled 'La Phénicie et les Phéniciens,' dealing with this and other matters connected with the geographical basis of Phœnician commerce and industry, a paper too that is apt to be overlooked, inasmuch as it was contributed by him with a generosity characteristic of one of the least self-seeking natures with which the world was ever blessed to a rather out of the way publication, the 'Bull. de la Soc. Neuchâteloise de Géog.' (vol. xii. 1900). But while I do not desire to enter into details regarding the Phœnicians it is necessary to point out how naturally and indeed inevitably this position of the Phœnician cities between the Mediterranean on the one hand and Mesopotamia and the Persian Gulf route to India on the other hand brought other sources of wealth in its train. Conveniences for the distribution of manufactured goods have always been one of the most important advantages for the development of manufacturing industry, and the wealthier the community forming the market for the products of such industry the more valuable are the manufactures likely to be. Hence the Phœnician manufactures of fine linens and woollens richly dyed, glass and metal wares, for which other parts of the Mediterranean and its seaboard furnished the raw materials, slaves to do the manual labour, and food for that population which the narrow strip of Phœnicia could not adequately supply. Food is indeed a bulky commodity, but even bulky commodities could be transported by sea at a relatively small cost, and in connection with this traffic we must note the indirect effect which the wealth of Phœnicia must have had in promoting the settlement of districts favourably situated for supplying food, and especially of such districts where the opportunities for producing food were great, but not fully turned to account, where the supply therefore could easily be made superabundant in proportion to the wants of the population. This shows that from the very nature of commerce its benefits are not confined to one side. Although the geographical conditions for a long period of time led to a special accumulation of the wealth due to commerce on Phœnicia, Phœnician trade promoted the growth of wealth and civilisation elsewhere. The Greeks of the Ægean distinctly recognised what they owed to the Phœnicians, and they in their turn derived much wealth from Eastern trade, even though not so directly as the Phœnicians, and they in their turn derived some of the food for a commercial population from the far west—from Syracuse, Sybaris, and even the distant Kume. But the far east had a peculiar fascination. As the articles from which much of the wealth of commerce was derived originally came from India, it was natural that the idea should arise that India was a wealthy country, a country well worth possessing. I am not

aware whether India ever was in historical times a wealthy country in the sense of producing a great abundance of the necessaries and ordinary conveniences and comforts of life in proportion to the population, but if it was not rich itself it was at least the means of making others rich. There can hardly be a doubt that the desire of possessing this country of real or imagined wealth was prominent among the motives that led Alexander the Great to embark on that enterprise which had such surprisingly—one might almost say miraculously—widespread, profound, and lasting effects on the history of the Near East. If we may accept as historical the speech in which Quintus Curtius represents Alexander as having addressed his troops after his victory over Porus, in order to encourage them to advance further into India, that speech affords fairly strong evidence of what has just been stated. 'What now remained for them,' said Alexander, 'was a noble spoil. The much-rumoured riches of the East abounded in those very regions to which their steps were now bent. The spoils accordingly which they had taken from the Persians had now become cheap and common. They were going to fill with pearls, precious stones, gold, and ivory not only their private abodes, but all Macedonia and Greece.'[1] Alexander was no merchant. Pepper was beneath his notice. His symbols of wealth are those which have always most powerfully affected the imagination. Later on, however, we shall meet with a king who was a merchant, and who understood perhaps better than Alexander wherein consisted the value of Indian trade.

At the outset of his career Alexander had destroyed Tyre, thinking, no doubt, that he had thereby wiped away the claims of one rival for a share of the wealth of the East; but it is a noteworthy fact that he did not thereby destroy the value of the site of Tyre under the conditions which then subsisted. Tyre revived and again obtained wealth from its trade with the East, as it did again and again in subsequent history. A heavier blow to Tyre than its mere destruction was the ultimate accomplishment of Alexander's idea for founding a great seat of commerce on the harbour which he saw could be created in the neighbourhood of the Nile delta. The foundation of Alexandria and the successful efforts of the successors of Alexander in Egypt to divert a large part of the trade in spices and other Oriental goods to the Red Sea route for the Mediterranean did more than a single act of war to deprive Tyre and other Phœnician cities of the peculiar pre-eminence which they had long enjoyed in the trade in those wealth-bringing commodities.

But perhaps the history of Venice shows even more clearly than that of Tyre the importance of this eastern trade in connection with certain inevitable geographical relations. The foundation of the future commercial glory of Venice may be said to have been laid when Rome planted her colonies north of the Po. The gradual clearing of forests gained for agriculture to a greater and greater extent one of the most favoured agricultural areas in Europe. There resulted a superfluity of agricultural products, which begot a trade by sea. The great outlet of this plain in Roman times was Aquileia, which in the beginning o the fifth century, when no one of discernment could imagine that there would ever be other than Roman times, was described by a Roman man of affairs and minor poet as one of the nine great cities of the world. But before that century was out Aquileia was destroyed, never to recover. The value of its site was replaced, and that in a strange way, which no man of discernment could ever have foreseen. The time that saw the destruction of Aquileia and the times that immediately followed were such as made safety a prime consideration, and especially for all who possessed or desired to possess wealth. Refugees from Aquileia, and afterwards from other Italian cities, thought at first of nothing but safety. Many of them found it on a few muddy and sandy islands near the muddy shores of the lagoon in which Venice now lies. But here they found the means of trade. The sea could be made to furnish both fish and salt, and the rivers that flowed into the lagoon enabled them to exchange these commodities for provisions of other kinds which the adjoining land could supply.

[1] J. W. M'Crindle, *The Invasion of India by Alexander the Great* (1893), p. 215.

Gradually this commerce grew, until in the eighth century we find the Venetians trading with Syria and Africa, Constantinople, and the ports of the Black Sea.

Throughout the period of growth the policy of this trading republic, both by land and sea, is very significant. Venice early realised the force of Bacon's maxim 'that he that commands the sea is at great liberty, and may take as much and as little of war as he will.' Power at sea was necessary to provide security for her commerce. In early times she generally owned allegiance to the Eastern Roman Empire, a suzerainty which could do her little harm and could and did do her much good. To that allegiance she adhered until she was strong enough to turn against and reap advantage from the overthrow of her suzerain. At an earlier date, before the close of the tenth century, she had conquered Dalmatia, and thereby destroyed the hordes of pirates who had found refuge in the innumerable harbours of that coast and constantly harassed the commerce of the Adriatic. At every opportunity she secured establishments and acquired possessions in the Levant.

On the land side, however, dominion would have added more to her risks than her advantages, and that dominion was not sought. For more than eight hundred years after the first flight to the islands of the lagoon, more than six hundred after the election of the first Doge (697), Venice possessed no territory on the mainland beyond a mere narrow ribbon on the edge of the lagoon. The nature of the situation made her indispensable to the trade of the land immediately behind. An incident belonging to the close of the ninth century illustrates the force of this observation. A keen dispute had arisen between the Patriarch of Aquileia and the Patriarch of Grado. Venice supported the Patriarch of Grado and war seemed to be threatened. But so necessary had the commerce of Venice become to the inhabitants of the territory acknowledging the authority of Aquileia that in order to bring about the submission of the Patriarch of Aquileia it was enough to close or blockade the port of Pilo, on the mainland opposite the *lidi*. The subjects of Aquileia then forced the patriarch to sue for peace.[1] On another occasion, in a dispute with the Bishops of Belluno and Treviso, the matter was again partly settled through the efficacy of the measures taken by the Doge Orseolo II., with the consent of the people, to stop commerce with the territory of the bishops, by which the inhabitants found themselves without supplies of salt, and without the means of exchanging their leather and meat for Venetian wares or selling the abundant timber of their forests for the building of Venetian ships.[2] In holding the outlets for maritime commerce Venice felt herself to be in the possession of 'the keys of trade,' to use the expression employed by Sir William Petty in speaking of the analogous position of Holland in later times at the mouths of the Rhine, Meuse, and Scheldt.

But while possession on the mainland was not necessary to Venice she always recognised and sought the advantage of good relations with the occupants of the plains behind her, whoever these occupants might be, and on every occasion endeavoured to turn to her own benefit the vicissitudes of those plains. In her early days she is found now in alliance with the Greeks, now with the Pope, now with the archbishops of Ravenna, and now with the Lombards, just as it happened to suit her interests, and in any case taking every opportunity of obtaining direct and indirect advantages from trade with the most profitable customers in the plains. When famine pursued the steps of the Lombard invaders of Italy in the sixth century 'the Venetians in their pacific retreat,' says Mutinelli,[3] 'could send their ships to the ports of Apulia and elsewhere to obtain victuals and corn for the famished barbarians,' and in consequence the Lombards took them under their protection and granted them security and favours throughout the Lombard kingdom. When Charlemagne, at the invitation of the Pope, invaded Italy to deliver the Church from its subjection to the Lombards

[1] Romanin, *Storia documentata di Venezia*, vol. i. pp. 197–8.
[2] *Ibid.*, pp. 270–1.
[3] *Del Commercio dei Veneziani*, p. 12.

Venetian traders promptly appeared in the camp of the Franks at Pavia and sold to the Frankish chiefs all the riches of the East—Tyrian purples, the plumage of gay birds, silks, and other ornaments, pranked in which the purchasers stalked about in their pride, feeling, no doubt, that now at last they had conquered a land whose wealth would reward all their labours and hardships.[1] Charlemagne, it is true, was inclined to look with little favour on the Venetians, whom he regarded as supporters of the Greeks, but an attack by his son Pepin in 809 on the islands of the lagoon only served to establish the strength and security of their position, at least on the inner islands of the lagoon. By closing the passages of the canals, removing the navigation beacons, and fortifying and barring the chief entrances to the land they succeeded in holding out during a siege of six months, till the heats of summer began to decimate the troops of Pepin, who, on hearing also of the approach of a Greek fleet, came to terms with the Venetians on conditions similar to those which had been maintained with the Lombards. The Venetians agreed to a tribute, but solely for the narrow strip of territory held on the mainland and in return for commercial privileges in the Frankish dominion, not for any recognition of the existence of the State. The tribute was afterwards paid or withheld according to the power which the Emperors showed of enforcing it; but one permanent result of this incident was that the Venetians, perceiving the smaller security belonging to the islands nearer the mainland, of their own choice made the Rialto the capital of their little State[2] (810).

As a last illustration of the nature of the relations of Venice to the North Italian plains we may refer to some of the points mentioned in a celebrated and often quoted address delivered to the principal senators of Venice by the Doge Mocenigo just before his death (1423), at the time at which Venetian trade was at the very height of its prosperity. At that time Venice was in possession of a considerable tract of adjacent territory on the mainland, and there was a party favourable to further action on the part of Venice against the growing power of Milan. The aged and sagacious Doge feared that this party was going to gain the upper hand and elect as his successor Francesco Foscari, who, he thoguht, would involve them in dangerous and disastrous as well as useless enterprises. The immediate occasion of the conflict of views in the Venetian Senate was a request of the Florentines for support against alleged designs of the Duke of Milan. Mocenigo, however, not only warned the senators in the most earnest and urgent language against Foscari personally, but also advised them against the particular enterprise, maintaining that it was of no consequence even if the Duke of Milan made himself master of Florence, since the artisans of Milan would continue to send their manufactures to Venice, and the Venetians would be enriched to the loss of the Florentines. He then went on to give particulars of the trade of Venice at that time, dwelling specially on the value of that with Lombardy. To Lombardy alone, it appears, Venice sold every year cloths to the value of 400,000 ducats, *tele* (? linens) to the value of 10,000 ducats: wools of France and Spain to the value of 240,000 ducats, cotton to the value of 250,000 ducats, wine to the value of 30,000 ducats, cloth of gold and silk to the value of 250,000 ducats, soap to the same value, spices and sugar to the value of 539,000 ducats, dye-woods to the value of 120,000 ducats, other articles 110,000 ducats: in all, goods to the value of more than 2,500,000 ducats, the profit amounting to quite half a million ducats. With the exaggeration that comes natural to a lover of his country Mocenigo goes on to say rather grandiloquently that to the Venetians alone land and sea were equally open; to them only belonged the carriage of all riches; they were the providers of the entire world.

All this trade, as well as that of Genoa and other Italian ports which shared with others in the spice trade, must have had a remarkably fructifying effect in North Italy generally. Agriculture and manufactures would be alike promoted,

[1] *De rebus bellicis Caroli Magni*, L. iii., quoted by Romanin, as above, vol. i. p. 130.
[2] Romanin, as above, vol. i. pp. 144–9.

and in consequence of that the growth of population; and when war, with its attendant scourges, led to a diminution both of industry and population, this commerce could not fail to assist in bringing about a speedy recovery. It has already been hinted that in manufactures both Milan and Florence took a prominent place in the time of Mocenigo. In truth, manufactures in both cities are of much older date, and it may be interesting to mention here that even in the thirteenth century English wool was a commodity sufficiently valuable to bear the cost of transport to Florence. A letter has come down to us,[1] dated London, January 6, 1284, from the representative of a Florentine house, giving particulars as to purchases that he had made, in many cases for several years in advance, of all or a portion of the wool of many English monasteries from Netley and Titchfield, in Hants, and Robertsbridge, in Sussex, to Grimsby, in Lincolnshire, and Sawley, on the Ribble, in the county of York (one of these monasteries, you may be interested to learn, as near Leicester as Monks Kirby, about midway between Rugby and Nuneaton), and from the work in which this letter is published we also get particulars[2] as to the cost of conveying wool from London by way of Libourne to the Mediterranean port of Aigues Mortes in the same or the following century. Florence, indeed, depended on England, Spain, and Portugal for wools of fine quality, its own and other wools of Italy being of very inferior value, so that when four bales of English wool were worth in Florence 240 gold florins the same quantity of wool of Garfagna dell' Aquila was worth only 40 florins.[3] The author of this work adds that he has found no indication of the prices of the wools of Spain and Portugal in Florence. Besides manufacturing cloths from the raw material 'Florence carried on a large trade in dressing and finishing woollens manufactured in Flanders and Brabant, and brought to Florence either by way of Paris and the Saône-Rhône valley or by way of Germany and across the Alps. In the time of Mocenigo many of these products of Florentine industry came to Venice for export. In the address already referred to Florence is said to have sent to Venice every year 16,000 pieces of cloth, which were sold to Aquila, Sicily, Syria, Candia, the Morea, and Istria.

It will be noticed that in the address above quoted Mocenigo lays no special stress on the spice trade, but there is not the slightest doubt that spices were amongst the most important commodities with which the Venetians provided a large part of the western world. Just as nowadays the large trade of Britain in bulky goods makes of this country a great entrepôt for the more valuable and less bulky, so in Venetian times the exceptionally large population behind Venice receiving and supplying the bulky goods thus fed the shipping which brought to Venice a much larger proportion of the more valuable goods of the East than was brought to other ports. But there is plenty of direct evidence of the importance of Indian trade to Italy in the Middle Ages. It is to be remembered that of necessity this trade enriched other countries before it reached Venice, and in proof of its importance in the Mediterranean generally one may call attention to the investigations of the Venetian Marin Sanuto Torcello about the end of the thirteenth century, who, we are told, saw with indignation that the defeats of the Christians in Palestine were specially due to the power of the Soldans of Egypt, and

[1] Published (1765) in a work having no author's name, but stated in the British Museum Catalogue to be by G. F. Pagnini della Ventura, and bearing the title *Della Decima e delle altre Gravezze della Moneta, e della Mercatura de' Fiorentini fino al secolo XVI.*, the third volume of which contains *La Pratica della Mercatura* of Balducci Pegolotti (ascribed to the first half of the fourteenth century), under whose name the work is entered in the British Museum Catalogue. The date of the letter is given on p. 94 of vol. ii., and the letter itself on pp. 324–7 of the same volume. For the identification of the names of monasteries in their much disguised Italian forms and spelling I am indebted to my friend Mr. A. B. Hinds, M.A., editor of the last issued volume of the *Calendar of State Papers (Venice)*. Most of them, however, are entered and identified in the list given from Pegolotti on pp. 629–41 of Cunningham's *Growth of English Industry and Commerce, Early and Middle Ages*, 4th edition (1905).

[2] *Ibid.*, vol. iii. pp. 261–3.

[3] *Ibid.*, vol. ii. p. 95.

perceiving that their great power derived its nourishment from the commerce with the Indies, based on that observation the projects which he urged on Christendom for the overthrow of that power. It is further significant that a sea way to India should have been sought by Genoese as early as 1291,[1] and even more significant that a century later Venice should have found it worth while to maintain a consul in Siam.[2]

But the clearest evidence of the supreme importance of the Indian trade to the Italian cities is to be found in the results of the discovery which finally diverted from Venice and the Mediterranean the great bulk of the Indian trade until that trade had lost all the special significance which it had retained for thousands of years. It need hardly be said that I refer to the discovery of the sea way to India by the Portuguese in 1497–9. Of the feeling aroused in Venice by this discovery Romanin has reproduced,[3] from the 'Diarii' of Priuli, an interesting contemporary record, written with reference to a despatch to the Doge probably from Pietro Pasqualigo, a Venetian envoy at Lisbon at the time of the return of the second Portuguese voyage to India under Cabral. The letter is stated to have reached Venice on July 24, 1501. After giving the letter, in which we are told, among other things, how the Portuguese had charged their ships at Cochin with spices at a price which the writer feared to mention, Priuli adds: 'On the arrival of this news at Venice all the city was deeply moved and remained stupefied, and the wisest held it for the worst news that could reach them. For, it being recognised that Venice had risen to so high a degree of renown and wealth solely by the commerce of the sea and by navigation, by means of which every year a great quantity of spices was brought thither, which foreigners then flocked together to acquire, and that by their presence and the traffic they obtained immense advantages, now by this new voyage the spices would be brought from the Indies to Lisbon, where Hungarians, Germans, Flemings, and French[4] would seek to acquire them, being able to get them there cheaply; and that because the spices that came to Venice passed through the whole of Syria and the countries of the Soldan, paying in every place exorbitant duties, so that at their arrival at Venice they were so weighted that what at first was of the value of a single ducat was raised in the end to sixty and even a hundred ducats; from which vexations, the voyage by sea being exempt, it resulted that Portugal could give them at a much lower price.' So said the wisest, but it is interesting also to note what was said by the less wise. Priuli goes on: 'And while the wisest saw that, others refused to believe the story [these, I presume, were the least wise], and others again said that the King of Portugal would not be able to continue this navigation to Calicut, since of thirteen caravels only six had returned safe, the loss would be greater than the advantage, and that it would not be so easy to find men who would consent to risk their lives in so long and perilous a navigation; that the Sultan of Alexandria, seeing the loss of so fine a profit as that obtained by the passage of the spices through his lands, would see to that.'

But in this case it happened that the wisest were right. The effects of this discovery were not long in making themselves felt in the notable diminution in the sales of spices at Venice. Under the date February 1504 Priuli enters in his diary, 'The galleys of Alexandria have entered into harbour empty: a thing never before seen.' In the following month the same thing happened in the case of the galleys from Beirut.[5] Under August 1506 it is stated that the Germans at the fair of the preceding month had bought very little. Various remedies

[1] See the account of this attempt and its results so far as they are known in G. H. Pertz, *Der älteste Versuch zur Entdeckung des Seeweges nach Ostindien.* Berlin, 1859.

[2] Romanin, as above, vol. iii. p. 335, note (5).

[3] As above, vol. iv. p. 461.

[4] We must recognise with due humility that the English are of little account in Venetian eyes in 1501.

[5] G. Coen, *Le Grandi Strade del Commercio Internazionale proposte fino dal Sec. XVI.* (Leghorn, 1888), p. 71.

for these evils were thought of, and among these it is interesting to note that in 1504 the Council of Ten seriously discussed a proposal to empower an envoy to the Sultan of Egypt to come to an agreement with him, if possible, for the cutting of a canal through the Isthmus of Suez.[1] But the proposal was not adopted. Other efforts to avert the results of the great achievement of the Portuguese were vain. Other disasters befel the republic about the same time. Not only was commerce taking another direction, but, says Romanin, 'the wars of Italy were emptying the treasury, the Turkish power was despoiling the republic step by step of its possessions beyond the sea, and Venice was beginning to descend that incline which was to reduce it to a subordinate position among the powers of Europe.'[2] North Italy generally suffered at the same time. The withdrawal of the greater part of the spice trade, by diminishing the growth of wealth among the inhabitants, made that part of the world a less important market for manufactured goods. Countries outside of Italy, where rival manufactures had already started, were increasing their wealth more rapidly, and thus imparting an increasing stimulus to their manufactures, and these increased while those of Italy declined. In 1338 the number of woollen factories in Florence is given at 200, making in all 70,000 to 80,000 pieces of cloth in the year; in 1472 the number of shops or factories had risen to 270, but no estimate is given of the quantity of the product; in 1529, however, the number of shops is said to have sunk to 150, and the quantity of cloth manufactured to 23,000 pieces per annum, and in the time of the editor of Balducci Pegolotti the quantity was only about 3,000 pieces annually.[3]

Before going further, however, there is one point in the comments on the discovery of the sea way to India quoted above from the 'Diarii' of Priuli which calls for notice. Hungarians, Germans, Flemings, and French, he observes, will in future go to Lisbon to get the spices of India more cheaply than at Venice. This remark illustrates the difficulty of shifting the geographical point of view according to circumstances, a difficulty of which at all times abundant illustrations can be offered. The purchasers of spices who come first into the mind of Priuli are Hungarians and Germans. It was inevitable that they should be among the leading customers of Venice. The Hungarians were supplied from the Dalmatian ports which belonged to Venice. The Germans came by way of the Rhine and the Elbe, and then across the Alps to get supplies for central, north-western, and northern Europe. But it was neither Hungarians nor Germans who came in greatest numbers to Lisbon to buy the spices which Portuguese ships brought from the East. In any case Lisbon had no advantages like those of Venice for supplying by land a large and rich population immediately behind it. The valley of the Tagus was small and poor, and had not the capacity for expansion in wealth and population which the Lombard plains had when the commerce of Venice began to grow. The bulk of the spices brought to Lisbon had therefore to reach their final markets by routes that did not pass through Lisbon into the interior. To supply the most important of those markets it was the Dutch, the people who held 'the keys of trade' for the important valleys of the Rhine, Meuse, and Scheldt, who came to Lisbon in greatest numbers to buy spices of the Portuguese. And here it has to be added that, in spite of the discovery of the sea way to India, the Venetians continued to retain great advantages in the spice trade with Hungary and parts of Germany, as well as, of course, the northern plains of Italy. Things did not remain always as bad as recorded in the years 1504 and 1506. The Portuguese, while maintaining successfully for a hundred years the monopoly of the trade in spices at the place of origin in the East, found their advantage in dividing the trade with Europe between the sea way and the Persian Gulf route, of which latter route they held the key since the final capture of Ormuz in 1515. The trade by way of the Tigris through Baghdad (the so-called Babylon of those days) and the Euphrates to the old Phœnician seaboard was again revived, and was maintained as long as Portugal held command of the trade. It was by this

[1] Coen, as above, pp. 82–3.
[2] As above, vol. iv. p. 466.
[3] *Della Decima*, as above, vol. ii. pp. 64, 105.

route that the first English commercial expedition to India, that of Newberie, Leedes, Story, and Fitch, went out in 1583, and by which Ralph Fitch, the sole survivor of that expedition, returned in 1591. By this route Venice got back some of her spice trade; not perhaps with the same profit to herself as formerly, but still a trade of no slight importance not only to Venice, but also to Augsburg, Nuremberg, and some of the other cities of South Germany.

But beyond doubt the bulk of the trade was now carried on by the sea route, and we are thereby enabled to get a better idea both of the amount and the nature of the trade. On both points we get information from the 'Narrative' of the above-named Ralph Fitch, who tells us that 'the Fleete which commeth every yeere from Portugal, which be foure, five, or sixe great shippes, commeth first hither [to Goa]. And they come for the most part in September, and remaine there fortie or fiftie dayes; and then go to Cochin, where they lade their Pepper for Portugall.'[1] Now in 1583 a ship of 500 tons would certainly be called a great ship. In 1572 the largest vessel sailing from the port of London was of 240 tons,[2] and the largest of the first fleet of the East India Company was one of 600 tons. I could give more definite information as to the capacity of these fleets at that time if I knew exactly what a *salma* was, for in a report on Portuguese trade sent to the Grand Duke Ferdinand I. of Tuscany (1587–1608) we are told that the fleet consisted of four or five carracks of the capacity of 5,000 or 6,000 *salme*.[3] But a *salma* is a term for which one sometimes gets a very indefinite meaning, at other times definite but very diverse meanings, sometimes a weight of 25 lb., which is obviously too little, and again a weight of 1,000 lb., which is probably too much. The large dictionary of Tommaseo gives this latter weight with an example stating the capacity of a ship; but if that were the meaning then the carracks would be of a burden of from 2,250 to 2,700 tons, a much heavier tonnage than is elsewhere indicated, so far as I am aware, for vessels of the period. Probably 3,000 tons would be the outside limit of the aggregate cargoes annually brought to Portugal, for in any case much room in the ships was required for the large crews of those days with their armaments, for then the idea of carrying on commerce by sea without being in a position to defend your ship was out of the question.

Of the commodities sent home from India, Fitch mentions in this place only pepper, and the correspondence of Albuquerque with the King of Portugal soon after the discovery of the sea way to India clearly reveals how all-important the pepper trade was; but it may be worth while to give the complete list of the commodities which Ralph Fitch enumerates at the end of his 'Narrative' as coming from India and the country further eastward. The list is not a long one. It comprises pepper, ginger, cloves, nutmegs and maces, camphora ('a precious thing among the Indians . . . solde dearer then golde'), lignum aloes, long pepper, muske, amber, rubies, saphires, and spinels, diamants, pearles, spodium, and many other kindes of drugs from Cambaia—all of them, it will be observed, having the character of being of high value in proportion to their bulk, so that a very great value of such goods might be carried in ships of small capacity.

Fitch does not tell us what was sent in return, but information as to that is to be had from other sources and presents one or two points of interest. In 1513 Albuquerque, after a long course of fighting, concluded a peace with the Zamorin of Calicut, in which it was agreed, among other things, that the Zamorin should supply the Portuguese with all the 'spices and drugs' his land produced, and that 'coral, silk stuffs, quicksilver, vermilion, copper, lead, saffron, alum, and all other merchandise from Portugal' should be sold at Calicut as heretofore.[4] Coral comes first in this enumeration. To us at the present day this does not seem a very important article of commerce, but it was otherwise then. One Mafio di Priuli, writing from India in 1537 to the Magnifico M. Constantino di Priuli, says, 'At a great fair which is called that of Tremel I have seen buttons of coral

[1] Horton Ryley, *Ralph Fitch*, p. 61. [2] *Ibid.*, p. 17.

[3] Angelo de Gubernatis, *Memoria intorno ai viaggiatori Italiani nelle Indie Orientali dal secolo XIII. a tutto il XVI*, p. 149.

[4] Danvers, *The Portuguese in India*, vol. i. p. 283.

sold for their weight in silver.'[1] That is the point of view of a European in India, but a native of the East Indies in Europe at the same date would no doubt have spoken with astonishment of the amount of silver that could be got in Europe for a few grains of pepper. Our letter-writer says in his cheerful, hopeful, gossiping way, 'The gains of these parts are other than those of Damascus, Aleppo, and Alexandria: for if one does not gain cent. per cent. from Portugal here, and from here back again, one thinks that one gains nothing. And three or four years would be quite enough.'[2] But, while he indicates how these immense gains are made, he also indicates clearly enough how they continue to be made—that is, how they are so counterbalanced by losses that if these great gains were not made on occasion commerce would cease. It was all very well to exchange your coral for spices, but the great matter was to get your coral out and your spices home in safety. The writer of this letter had entrusted to a friend who had left on a ship for Ormuz jewels of the value of 4,000 Venetian ducats, but the jewels were lost. He believed that his friend was murdered. 'But such losses,' he adds, 'will occur.' Another time he lost more than 6,000 ducats gold in Portuguese vessels going to Ormuz, and on another occasion he suffered great loss when Pegu was sacked by the King of Burma.

These notes may serve to illustrate the conditions of trade in the glorious days for Portugal when fine fortunes were heaped up in Lisbon through trade, but the great bulk of humanity got very little at least directly through that trade; but we have not exhausted the interest connected with the nature of the outgoing commodities for India, and to that it will be well to return. Another of the stipulations of the treaty of 1513 above referred to was that while duties were to be paid in coin 'the Portuguese were to pay for all the pepper and other merchandise they might purchase in kind,' and, as the peace led among other things to a dearth of prizes, Albuquerque 'was constrained to send an urgent request home for large quantities of merchandise to be sent out to make up for this deficiency.'[3] How long this stipulation remained in force I cannot say, but things were certainly different a hundred years later. In the report to the Grand Duke of Florence above cited we are told that what the Portuguese carry to India for exchange is above all 'silver in reals, and besides silver wine, oil, and some other sort of merchandise, such as coral, glass, and the like, of little importance'; and as to the silver he adds that 'the reals bring a gain of more than 50 per cent. as soon as they have reached India, for the real of eight, which in Lisbon is worth 320 reis, in India is sold and spent at the rate of 480 to 484 reis of that money, and with it one buys all sorts of spices and drugs which are sold there, except pepper, which is the monopoly of the King of Portugal and those to whom he gives a lease of that trade.' The importance of silver among the outgoing commodities for India has continued from that time down to the present day, latterly, however, in diminishing proportion. For a long time after the date at which we have now arrived it was as predominant as a means of exchange with India as it was in the first century of the Christian era, when the drain of silver from the Roman Empire to the East was bewailed by the writers of that time. In the voyages of the English East India Company of the four years 1620–23 inclusive the value of the bullion (chiefly silver) sent out to India was 205,710*l.*, as against only 58,806*l.* worth of merchandise.[4]

Now, what is the meaning of the change in the position of silver in Indian trade which seems to have taken place between 1513 and the end of the sixteenth century? No doubt we may see there the result of another change in geographical relations brought about by a discovery nearly contemporaneous with that of the sea way to India—namely, that of the New World. The first result of that discovery of importance to commerce was the pouring into Europe of large quantities of the precious metals, and the quantity was enormously enhanced

[1] P. 34 of the letter referred to as published at Venice in 1824.

[2] *Ibid.*, p. 29.

[3] Danvers, vol. i. pp. 284, 286.

[4] I take these figures from p. 6 of the appendix to P. Colquhoun's *Treatise on the Wealth, Power, and Resources of the British Empire*, 2nd ed., London, 1815.

after the silver mines of Potosi, in Upper Peru (as it was then called), were discovered in 1545. It was probably this discovery that brought it about that of all commodities of such small bulk in proportion to their value as to stand the costs of transport to the East this was the one which could be sent out for most part with the greatest advantage. And this discovery no doubt also helps to explain why that of the sea way to India had so little effect for a very long time in lowering the prices of spices in Europe, why prices even rose. At the time of the return of Vasco da Gama from the first voyage to India the price of pepper at Lisbon is estimated by Danvers[1] to have been about 1*s*. 5*d*. per lb., and we all know that the immediate occasion of the foundation of the English East India Company about a hundred years later was that the Dutch suddenly raised the price of pepper against the English from 3*s*. to 6*s*. and 8*s*. per lb.

But the particular commodity which made up the principal portion of the outward trade to India is, after all, a matter of detail, though not unimportant detail. The main point on which I want to insist is that, whatever the commodities were, whether carried out or home, the nature of the trade with the East was little if at all altered by the discovery of the direct route to India by sea. The trade still continued to be one concerned in a moderate number of articles of small bulk but high value. It was merely a change of route that the Portuguese effected, and for more than a hundred years they remained in sole command of this route. After that, however, they were ousted from the greater part of this trade, and that the more valuable part, chiefly by the Dutch, and from a geographical point of view it is very interesting to note how the Dutch did it. They did not trouble themselves much about India proper. They left the Portuguese alone at Goa, and from that port as a base allowed them to pick up as much trade as they could at Calicut and Cochin, which, said Albuquerque, 'were capable of supplying the Portuguese fleets until the Day of Judgment.' But Malacca, on the straits of that name, gave command of the route to the further East, whence came in the end even larger quantities of pepper than could be got from India, whence came too ginger, cloves, and nutmegs, as well as the products of China. The importance of this place Albuquerque had accordingly recognised, and in 1511, the year after he took Goa, he took it also by the right that always belongs to the lion as against the jackal. This place was taken by the Dutch (1641), who had previously established themselves on Java and the Spice Islands, where they maintained an absolute monopoly. Ceylon, again, was (and is) almost the only place from which the true cinnamon was to be obtained, so the Dutch took that island also from the Portuguese (1656). As long as the Portuguese were the sole Europeans in the East, Calicut and Cochin not merely furnished the Portuguese with Indian wares, but were important entrepôts for the spices, perfumes, drugs, and jewels of the Further East as well as of Chinese silks and porcelains; but the trade in these commodities could be wholly or largely diverted to places in the possession of the Dutch. Even before the capture of Malacca and Ceylon a Portuguese viceroy had reported (1638) that the Dutch had a monopoly of trade from the Bay of Cochin China to the point of Sunda.

But this change also was little more than a change of route. The general character of the Eastern trade remained the same. The English East India Company, whose operations, through the hostility of the Dutch, came to be restricted to India proper, there founded a trade that gave much more opportunity for expansion under modern conditions than that of the Dutch, but for a long time it retained the same character. All the commodities enumerated by Colquhoun as brought back by the voyages of 1620–3 in exchange for the bullion and merchandise sent out were pepper, cloves, mace, nutmegs, Chinese and Persian raw silk, besides calicoes, the sole manufactured article, and one of course that had relatively a much higher value than now, when the direction of the trade in that commodity is reversed.

A similar character for a long time belonged to the trans-Atlantic trade, even though the costs of transport in that case were less, and favoured the development of a trade in somewhat bulkier commodities. Furs from the Far North,

[1] As above, vol. i. p. 64.

tobacco from Virginia, sugar and afterwards coffee and cotton from the West Indies, were by far the most prominent imports. It was the tobacco trade of Virginia that first enabled Glasgow, which at the time of the union of the English and Scottish Parliaments was an insignificant town with less than 13,000 inhabitants, to convert itself into a seaport, and thus lay the foundations of its subsequent prosperity. Now tobacco makes up less than one per cent. of the value of the goods imported at Glasgow, and, though that may be partly due to a diminution in the actual quantity of tobacco imported at Glasgow, this result has chiefly been brought about by changes in relative values. A hundred years ago the value of the imports into Great Britain and Ireland from the British West Indies was about one-fourth of the total value of the imports from all parts; now it is less than one per cent. of that value.

What has brought about such changes, what makes the essential difference between recent and all previous commerce, is the series of enormous improvements in the means of communication which followed so closely on the invention of textile machinery and the improvement of the steam-engine in this country. These improvements have had two important effects on commerce. First, they have facilitated the maintenance of order and security both by land and sea, and thus enormously reduced the risks of commerce. Secondly, they have directly lowered the cost of transport for different goods in different degrees. Bulky goods of little value could now for the first time be profitably conveyed many hundreds of miles by land to a seaport, and there load ever larger ships for distant shores, thus opening up markets with vast undeveloped resources in the heart of great continents. Along with these bulkier goods the more valuable goods are carried at a cost far below that of former times, so that for such commodities as pepper the mere freight is almost a negligible item.

At the present day there can be no doubt that in point of quantity the spice trade is much larger than it ever was. If Venice could get the whole of that trade into her hands, a thing which she never had, notwithstanding the patriotic boast of Doge Mocenigo, the trade would not now bring her a tithe of the wealth which it brought in the days of her grandeur. Much has been said of the sudden 'fall' of the Portuguese and Dutch in turn, and that fall has often been explained by mistakes in method. 'The fall of the Dutch colonial empire resulted,' says Sir William Hunter, 'from its short-sighted commercial policy. It was deliberately based upon a monopoly of the trade in spices, and remained from first to last destitute of sound economical principles.'[1] But one may well ask, Did the Dutch ever fail in a manner for which they were in any way responsible? It is true that the Dutch East India Company did not supply as many people as they could with the spices of which they held the monopoly. But that was not their aim. It is true that they did not build up a great empire like that of the English East India Company. But neither was that their aim. Their aim was to declare dividends, and dividends they declared. The profits of the company down to 1720 averaged 20 per cent. per annum, never sinking below 15 per cent., and sometimes rising to 50 per cent. If spices ceased to enable them to declare such dividends that was not their fault. It was James Watt, George Stephenson, William Symington, and Robert Fulton, who, without intending it, and without being able to foresee what in this respect they were destined to do, sucked the value out of pepper, and that in a manner which neither the strength of armies nor the subtlety of statesmen could have done anything to prevent.

Now the countries that offer the most attractive markets for the greatest quantities of goods of all kinds are no longer those which look to the spice trade or to trade in any specially valuable commodities for their enrichment, but those which abound in coal so placed as to develop a great amount of manufacturing industry, an industry engaged for the most part in working for the million, not merely in producing the luxuries of the rich. The commodities of very small bulk in proportion to their value now have a comparatively insignificant place

[1] *Imperial Gazetteer of India*, 2nd ed. vol. vi. p. 362.

in commerce. The precious metals and precious stones still indeed retain a good deal of their former importance. But very few vegetable or animal products can be put in the same category. Rubber, indeed, may be reckoned as one, and very handsome profits are reaped from some rubber estates. But everyone knows that such exceptional profits can be reaped only for a short time. Of animal products ornamental feathers are the most valuable in proportion to their bulk. Egrets' feathers, I believe, are seldom worth less and often worth a good deal more than twice their weight in gold, but ornamental feathers altogether make up less than a third of 1 per cent. of the total value of British imports.

Perhaps the greatest feature of modern commerce is the unparalleled manner in which it has promoted the increase of population nearly all the world over. Rendering it possible for manufacturing and commercial peoples to depend in a very large measure for their very means of subsistence on supplies brought from the ends of the earth, it is rapidly pushing the settlement of vacant land to the base of the mountains and the edge of the desert. Fifteen years ago Professor Bryce said, 'We may conjecture that within the lifetime of persons now living the outflow from Europe to North America will have practically stopped.'[1] We are at least nearing the time when the 'new lands' of this earth in the temperate zone will all have been allotted. The results of such a check to expansion after a long period of stimulation to expansion must be momentous, but what the nature of these results will be I for one confess that I am unable to foresee. I am, however, convinced that, if we are to be enabled to make any probable forecast as to the course of future development, one of the most important aids to that result must consist in the study of the relations of geography and history from the point of view which I have endeavoured to indicate. To study these relations merely with reference to the immediate causes and effects of wars and treaties gives little real insight into the working of geographical influences in history. As in the study of the human body medical men have recognised the necessity of ascertaining with the aid of the microscope the normal functions of the cells of which the body is composed, the pathological states that interfere with their normal working, and the effects on one part of the body of minute disturbances of function in another part, so in tracing the course of history it is becoming more and more recognised that the minute gradual silent changes must be inquired into and taken into account, not merely in relation to the regions in which they take place, but in relation, it may be, to regions far distant. Such studies, it is true, are not confined to the geographer. In them, indeed, the geographer must seek the aid of workers in other fields; but there can hardly be a doubt that it must help greatly towards arriving at a sound solution of the problems presented to keep steadily before one the geographical point of view. The field for such studies is of course immense, the material perhaps not all that could be wished; but I can imagine no task more delightful for those who have the opportunity to engage in it than that of seeking out and examining from that point of view such material as actually exists.

The following Papers were then read:—

1. *The District of Jæderen in Southern Norway.*[2] *By* O. J. R. Howarth, *M.A.*

The district of Jæderen extends south of the port of Stavanger, on the Birkren Fjord. South of this fjord is the principal of the few interruptions to the *skjærgaard*, or great fence of islands which protects practically the whole coast of Norway. At first this coast is unbroken, low, and shingly, backed by a slightly undulating coastal belt, bare and abounding in peat-bogs, from the landward edge of which hills rise abruptly. There then succeeds a coast with rocky prominences

[1] 'The Migrations of the Races of Men considered Historically,' in the *Scottish Geographical Magazine*, 1892, p. 419.

[2] To be published in full in the *Geographical Journal.*

alternating with sandy beach, and still practically without islands, which extends nearly to the port of Egersund, when the characteristic steep, broken coast, with many islands (though not so many as to the north of Stavanger), is resumed. This intermediate stretch of coast belongs to a peculiar region, which is defined inland by a sharp range of mountains to the north, and by mountains and the valley of the Birkren River to the east. Beyond these boundaries is found the typical scenery of Southern Norway; within them the scenery is wholly individual in character. The district is still hilly but less elevated, the hills rise in semi-isolated clumps, and the whole is practically an unbroken tract of naked rock, which reveals, to an extent dominating every other feature, and scarcely equalled elsewhere in this intensely glaciated country, the work of the glacier which once covered it. The perched blocks scattered all over it, the innumerable hollows carrying little lakes, and the remarkable manner in which at many points huge boulders are piled together and riven, all illustrate the action of the same force. Moreover, the coast of this district demonstrates peculiarly well the upward movement of the land which is traceable elsewhere. A succession of lowlands separated by high ridges indicates former small fjords; an old beach may be traced at a considerable distance inland; and through the sand-dunes and marshes along the shore high rocky eminences stand up, clearly once islands. But the rocks immediately upon the coast show that at the period of glaciation the land stood higher than it does now, and thus indicate an intermediate period of sinking. The diverse physical characteristics of Jæderen exercise a notable effect on the distribution of its population.

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2. *Commercial Geography from the Modern Standpoint.* *By* Professor MAX ECKERT.

Anthropogeography, or the geography of mankind, as brought into existence within the last few decades, is essentially the study of the relations of man to his native soil. It is an independent branch of geography, as it deals with a special group of facts and ideas, and its object is to trace the connection between the several factors—geographical, historical, and social—which come into play.

The geography of mankind is the one subject of study which supplies an adequate bond of union between the natural and moral sciences. In it the attention is focused, in the first place, on the moral side, since it pays regard to the moral influences which underlie human action, past as well as present; and in the next place, on the natural side, since it bases all its considerations on the physical conditions of the earth, and by the aid of scientific induction evolves general laws regarding the influence of the soil on man, and of man on the soil. It is the latter consideration which is of special importance in the study of human geography.

One of the most important bases of anthropogeography is the study of the geography of settlements, which teaches us how man exploits the ground on which he dwells for the satisfaction of his requirements. With the multiplication of his economic interests man passes beyond the narrow bounds of his dwelling-place and native sphere of action, entering into commercial intercourse with his neighbours, and even with more distant peoples.

The character and problems of commercial geography, in the modern conception of the term, are briefly as follows: Starting from a knowledge of the location, the orography and hydrography of a given region, it must also consider certain aspects of its climatology, geology, political economy, and political geography, and thus arrive at a clear conception of the conditions of production and commerce within such region, as well as throughout the earth as a whole. Or, in fewer words, commercial geography must view the earth as the theatre of human production and commerce.

Regarded from the economic view-point, commercial geography must not only determine the places of occurrence of natural and industrial products, but must study the factors which govern such occurrence—*e.g.*, the latitude and altitude of

the places, their climate and water-supply, and last, but not least, the composition of the soil and variations of the climate.

Regarded from the commercial point of view, it has to consider the methods and apparatus of traffic, and the goods forwarded by such apparatus. An important problem is the determination of the regional distribution of the various kinds of routes and means of transport; while other subjects to be studied are the various classes of commerce, railways, sailing and steamship routes, ports, and the like.

Joint Meeting with Sections C, D, and K.

The Preservation of Natural Monuments. By Professor CONWENTZ.

FRIDAY, AUGUST 2.

The following Papers were read:—

1. *The Surveys of British Africa. By* Major C. F. CLOSE, *R.E.*

It is perhaps not generally known that during recent years a good deal has been done to ensure the systematic mapping of British Africa. There are at the present moment properly organised survey departments in the Anglo-Egyptian Sudan, Uganda, East Africa, Southern Nigeria, and the Gold Coast. In addition, an exact topographical survey is in progress in the Orange River Colony; and in the Cape Colony a military reconnaissance survey has been at work for two and a half years.

The annual cost of the surveys above enumerated amounts to some 80,000*l.*

An account of the progress made, the scales adopted, and the history of the surveys will be found in a Colonial Office Annual Report, No. 500, entitled the 'Surveys of British Africa.'

Unfortunately, official reports have a limited circulation and public departments cannot very well advertise their achievements. As a consequence, all this systematic work, which produces surveys of a permanently valuable character, is largely unknown to the geographical world.

It is clearly desirable that that section of the public which takes an interest in the matter should be informed as to the steps which are being taken to map and explore British Africa, which, it may be noted parenthetically, covers an area of about 2,690,000 square miles.

During the current year about 45,000 square miles will have been topographically surveyed, and to this must be added a large number of compilations, the surveys of boundary commissions, and cadastral surveys. The maps are put on sale as they are published, and can be purchased from the usual map sellers and agents. Anyone desiring special information on the subject is advised to write to the Secretary, Colonial Survey Committee, Colonial Office.

2. *The Modern Explorer: his Maps and Methods.*
By Captain T. T. BEHRENS, *R.E.*

The author said that the paper dealt with temperate and tropical conditions, and not with the special circumstances of surveys in the Arctic. He proposed to explain the methods of African field-work by lantern-slides illustrating operations of this nature in East Africa and Uganda. These surveys had recently fixed the positions of Mounts Ruwenzori and Mfumbiro, on the Congo border.

The completion of the maps of the whole land surface of the globe on atlas scales has been made possible by the rougher exploratory methods of the past.

Further advance in our knowledge of the configuration of our planet can only be made by more detailed surveys; and whereas this was formerly impossible, the extension of cheap and rapid means of communication into the very heart of the explorers' retreats in all parts of the world renders it now not only feasible, but economically desirable. The methods of the past are entirely unsuitable to the production of more detailed maps on larger scales; and money must be spent not on producing long, narrow, disconnected lines of traverse, but in compact and accurate surveys of those areas that most require our study.

The methods employed will vary in accuracy according to the conditions in each particular case; but they will in general be modifications of those in use in any organised topographical survey department. At times, even, it may be that the methods will be those of the geodesist. As in every other production of human effort, increased accuracy means an increasing rate of increase in the cost. Before embarking on a survey we must therefore consider well the exact purpose for which the resulting map is required. An expert with large practical experience and the details both of field and cartographic work at his fingers' ends can then decide exactly what methods will economically produce the desired result.

In conclusion, we must not forget that to the explorer, in whatever branch of science he may be interested—whether it be geology, botany, or any other of the many branches of natural science—accurate maps on topographical scales become daily of greater importance; each subject becomes more highly specialised, and research is daily made in greater detail than before.

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3. *Recession of the Niagara Falls. By* Dr. J. W. Spencer.

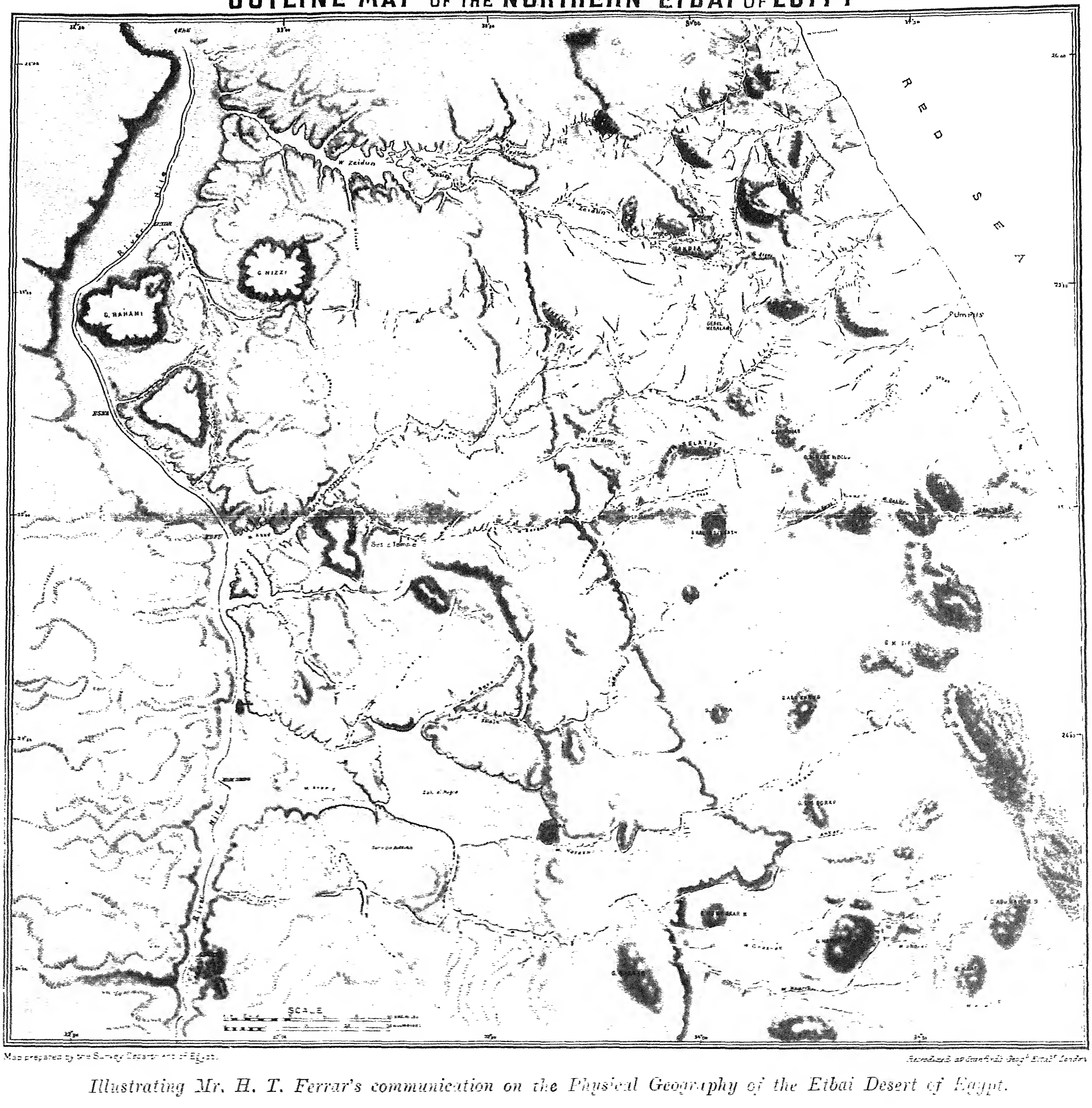
For many years Niagara Falls and the Great Lakes of America have been special subjects of the author's researches. These have at last been completed under commission from Dr. Robert Bell, Acting Director of the Geological Survey of Canada, and later of A. P. Low, Esq., Director, the results being obtained through precise instrumental measurements, borings, and soundings, the last of which had not previously been undertaken. The recent survey of the crest-line (1904–5), compared with that of Professor James Hall (1842), shows the mean rate of recession to have been 4·2 feet a year, the average breadth of the gorge produced by the Falls being 1,200 feet. But a longer record (agreeing with the more recent) has been obtained by Mr. James Wilson and the author in the determination of the position of the Falls in 1678, from the crude description and picture made by Father Hennepin at that time. Between 1890 and 1905 the rate of recession diminished.

Soundings under the Falls and throughout the gorge were obtained by the use of Tanner-Blish self-registering tubes, acted upon by the hydrostatic pressure, as the current was too strong for the use of an ordinary line. At the whirlpool, and at some other places, it was necessary to work from a cable swung across the gorge. Under the Falls themselves the sounding-tubes were inserted in a specially designed buoy, which the force of the fall drove down to the rocks that had collapsed beneath the Falls themselves. These were reached at 72 feet, while the floor of the river beyond varied from 84 to 100 feet below the surface of the river. Further down there was a lateral inner gorge, reaching to 192 feet, which could not have been produced by the present descent of the Falls. An explanation of this, however, was found.

The river at the whirlpool was measured to a depth of 126 feet; but this was not quite in the middle of the current, where the depth is supposed to be 14 feet greater. Below the whirlpool the river is shallower. From a short distance below the Falls, as far as the whirlpool, the bottom of the channel is at a depth of about 90 feet below the level of Lake Ontario.

At points a short distance within the end of the gorge, and also beyond, a narrow, deep, inner channel, reaching to about 180 feet below the level of Lake Ontario, was discovered. This established the fact that the aggregate height of the different parts of Niagara Falls was more than 500 feet.

OUTLINE MAP OF THE NORTHERN ETBAI OF EGYPT



Map prepared by the Survey Department of Egypt.

Reproduced at Stanford's Geog.l Estab.t London

Illustrating Mr. H. T. Ferrar's communication on the Physical Geography of the Etbai Desert of Egypt.

A terrace formed upon the birth of the Falls shows that they were at first only 35 feet high. The present height is 158 feet, while the fall along the different parts of Niagara River reaches 326 feet.

During the long earlier history of Niagara there were at first two, and later three, separate cataracts. The upper two united when the Falls had receded about three miles; the third joined the others later, but it had no effect on the recession of the main falls, as it was soon reduced in height by the backing of the waters of Lake Ontario. Until this time, when the Falls had passed the point of union by only 600 feet, the volume of the river was 15 per cent. of the present amount. It was now increased to its full amount, with the result that the floor of the cañon was broken through to a depth of 135 feet. This augmentation resulted from the accession of the drainage of Lakes Huron, Michigan, and Superior, which formerly drained to the north-east, and only now joined the Lake Erie discharge, the change being due to a tilting of the earth's crust, which culminated only 3,500 years ago. The upper rapids are due to the river recently reopening a buried valley and descending over its eastern slope. This valley, however, did not trend northward, but southward. Accordingly, the upper rapids have had little to do with the recession of the Falls.

It thus appears that the rate of recession has been modified by changes of volume and of height. These features and the character of the rock-formation, as well as the buried valleys, are now known for every furlong which the Falls have receded. If we apply the laws of erosion to these changing features the result will indicate that the time required for the recession of the first three miles was 35,000 years, but for the last four miles only 3,500 years, which gives a total age of 39,000 years. As all the changing conditions are now known, it appears that the probable error does not exceed 10 per cent. This, the author claims, is the only computation of their age which has been made upon measurements of all the changes in the physics of Niagara Falls.

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4. *The Physical Geography of the Etbai Desert of Egypt.*[1] *By* H. T. Ferrar, *M.A., F.G.S.*

[Plate IV.]

The author exhibited an outline map of the Northern Etbai, which he had prepared as an experiment in order to bring out the main physical features of the country. It had been traced from more detailed plane-table sheets on the same scale (1:100,000) and adjusted to the chains of triangulation stations which cross the country, but many of the details had been omitted. The work of the author's colleagues, Drs. Hume and Ball, which should appear on the eastern border of the sheet, was also omitted, but could be seen on a smaller sheet (scale 1:500,000). The hill-shading might almost be called diagrammatic, as no attempt had been made to depict more than the most important geological and topographical features which abound in this hitherto unmapped country.

Many explorers have made traverses through the deserts, but their maps are on rather a small scale, and apart from a few place-names the data were so scanty that the whole country has had to be re-explored. Of special interest are the following points:—

1. *Basins.*—Floyer[2] has drawn attention to the fact that the wadis draining westward from the water-parting are centripetal. The map shows three of these basins, viz., Qena, Edfu, and Kom Ombo.

2. *Beheading.*—As in South Africa, so here the gentler sloping western wadis have been beheaded by the steeper eastern ones, *e.g.*, Rod Um el Farag by Wadi Dabur; Wadi Zeidun by Wadi Dubbagh.

3. *Mushels,* i.e., the forking or branching of wadis owing to the aggraded

[1] By permission of the Director-General, Survey Department, Egypt.

[2] *Quart. Journ. Geol. Soc.*, vol. xlviii. p. 576.

state of their beds, *e.g.*, Wadi Abu Hamamid, Rod el Moghalat; and more especially Wadi Hendosa and Wadi Abu Tiur, which have the same source.

4. *Arabic geographical terms*, such as Gebel, Wadi, Rod, Kob, Talla, Khor, Sowahil, Dahariah, Ghradir, Galt, Bir.

5. *The history of the region*, with special reference to (*a*) the Nubian Sandstone escarpment; (*b*) the age of the drainage system; (*c*) indications of a former pluvial period; (*d*) high-level gravels and alluvium; (*e*) the wide distribution of celts.

5. *The Kurdish Tribes of Asiatic Turkey.* *By* Mark Sykes.

From Uruma, in Persia, to Angora, in Asia Minor, there is scattered a nation or a group of people who have suffered considerable neglect at the hands of history and science alike. These are the Kurds—nomadic, semi-nomadic, and sedentary. Except that they are credited with a multitude of imaginary vices and are looked on as ignorant savages, they receive but little attention from the people either of Asia or of Europe. Fortune has enabled the author to make certain investigations concerning these people, among whom he finds such startling variety in physique, dress, and custom that he is unable to generalise on their characteristics, save in a very diffident manner. He has distinguished and marked on the map about 323 tribes and sub-tribes, which at a venture may be said to contain a population of close on 2,000,000.

It is very difficult to say how the Kurds should be classified. As regards religion, there are to be found among them Sunni Moslems, Shias, Devil-worshippers, Pagans, and Christians. As to language, they are split up into a variety of dialects which are said to form two broad divisions, called respectively Zaza and Kermanji. In regard to appearance and physique there are, again, the most unexpected and astounding contrasts: small, wiry, agile mountaineers in Hakkiari; tall, slim horsemen in Irak; big-boned, heavily built, hook-nosed, and clumsy men north of Lake Van; stout, full-bearded men with regular features in North Mesopotamia; fair-haired and ruddy-complexioned men north and west of Erzinjian; and straight-featured, exceedingly handsome men in Kochkiri.

In respect of civilisation and mode of life we again find surprising contrasts. In Irak the Kurds are generally shepherds, but in the northern mountains south of Lake Van they are industrious agriculturists, some of whom build fine houses and castles. North of Lake Van they are idle; in the Dersim they are more than industrious; in Mesopotamia they are wholly nomads; in the western Taurus they are often degraded and poverty-stricken; in the valley of Erzinjian they are capable and wealthy agriculturists.

Consequently the author is unable to advance any theory, and ventures only to bring forward a certain amount of information which the historian and man of science may find useful in the future.

MONDAY, AUGUST 5.

The following Papers were read:—

1. *The Land's End Peninsula: a Regional Survey.* *By* A. W. Andrews.

The Land's End peninsula consists of a granite plateau, of which the higher part is from 400 to 800 feet in elevation and about eleven miles in length by four in width, extending in a south-westerly direction from St. Ives to the Land's End. This largely consists of moorland covered with furze and heather, but almost entirely bare of trees, owing to its wind-swept character. The hills which rise from the plateau are generally undulating, and only here and there assume bold shapes, though they are crowned by masses of granite boulders many of which are not inferior in size to the tors on Dartmoor.

The whole area is almost unpopulated and has few industries, though the old mine shafts and adits made for prospecting purposes point to much greater activity in former days. Almost the only industries which now exist are connected with the granite, a small amount of the fine-grained moorland granite being quarried, though it cannot hold its own against the cheaper sea-borne Norwegian stone. There are also china-clay works, as at Towednack. It is possible that the modern demand for tin, wolfram, and other rare minerals may result in some of the old mines being reworked, but as yet very little has been done on the plateau.

To the north and west of the plateau is a narrow coast plain, of less than a mile in width, which was probably covered by the sea in Pliocene times to the height of 340 feet. This is employed for agricultural and pastoral pursuits, but the soil is poor and unproductive. The valleys which seam the plateau on these sides are not well marked, and the streams are small. The coast is, as a rule, lofty, with striking granite and greenstone cliffs, and is almost harbourless, few coves being accessible for even small fishing-boats. The only important centre of population is in the neighbourhood of St. Just, where the Levant mine and that newly reopened at Botallack employ a considerable number of miners. On the south of the higher plateau the streams are longer and the valleys deeper, many of them being thickly wooded. The soil is much richer, especially near Penzance, where the greenstone predominates, and where industries such as the cultivation of cauliflowers are of considerable importance, land being let at from 12*l.* to 14*l.* per acre. The climate is far warmer and milder, the region being largely sheltered from winds.

The whole peninsula is separated from the rest of Cornwall by a neck of low land. Though small, it has sufficient characteristic features to mark it off from the rest of the county, and is specially interesting as a type of a somewhat isolated area of old rock, in that respect resembling the inland region of Charnwood Forest.

2. *The Hinterland of the Port of Manchester.* *By* J. McFarlane.

The imports of Manchester by way of the Ship Canal are much greater than the exports. Among the former are cotton, grain, timber, paper-making materials, fruit, oil, &c. The area over which American cotton is distributed from Manchester does not correspond with the area over which rates are less than from Liverpool. The latter town has acquired a momentum as a cotton market, which at present more than counterbalances the geographical advantages of Manchester. A large proportion of Egyptian cotton comes, however, to Manchester and is distributed to the towns in the neighbourhood.

When the commodity is imported by one firm or company, or when the market conditions are simple, Manchester is able to avail itself of its geographical advantages to a greater extent. Grain, oil, and fruit are distributed over a considerable area, varying in each case, but generally covering the east of Lancashire, the west part of the West Riding, and some of the Midland towns within 100 miles of Manchester.

The exports are insignificant as compared with the imports, but coal from the Lancashire field is shipped in considerable quantities. There are several reasons for the small export trade. The total shipping is not yet very great, and facilities for export are frequently wanting. Shipping rings also seriously affect the development of the port in this respect.

3. *The Geographical Evolution of Communications.* *By* Professor Vidal de la Blache.

Man had originally no other means of travel and transport than himself. But, whether for the purpose of adjusting or hauling loads, of surmounting obstacles, or of venturing on the water, he has had recourse to devices the

invention of which points to varying environments and a multitude of independent initiatives, the local flora and fauna furnishing the material for this primitive apparatus. A great step in advance was made in the adaptation of animal power to purposes of transport, and this ensured the superiority of such countries as afforded the opportunity for the recruitment by man of his best auxiliaries. This kind of domestication had its origin at many different centres. The horse was doubtless brought under man's control independently in many countries of Central Europe and Asia; the camel, in Central Asia; the ass, in the Sudan, Upper Egypt, &c. The vast region of plains or steppes, with bare uniform surface which crosses Europe and Asia in a diagonal direction, favoured the development of long-distance traffic, as is proved by the numerous improvements in the wheel and cart which were there introduced. But this ancient transport had to do rather with human beings than with dead freight. To the domestication of the horse we may attribute the origin of the great migrations which took place in Central Europe from the close of the Neolithic Period onwards, and which were destined to cease only with the definite crystallisation of modern States. Even the interior traffic of later times originated in the movement of distant products, such as jade, silk, and certain metals.

4. *Explorers and Colonists.* *By* J. D. Rogers.

5. *A Narrative of the Jamaica Earthquake.* *By* Vaughan Cornish, *D.Sc., F.R.G.S.*

Dr. and Mrs. Cornish were in a house in Kingston at the time of the great earthquake of January 14, and the author described the incidents attending their remarkable escape from the wrecked room.

He next dealt with the occurrences in Kingston during the days of stress which followed, showing many original photographs of the effects of the earthquake on buildings, and describing the camp-life in the ruined city and the conduct of different classes of the community.

Early in May, Mrs. Cornish having recovered from injuries received in the earthquake, the author and his wife made a second voyage to Jamaica to investigate the cause and effects of the earthquake, returning on July 17. A description was given of the methods of inquiry adopted to determine the place of origin of the earthquake, the character of the shock, the effects upon buildings of different kinds, and other matters; and a further collection of photographs taken by the author was shown.

A final account of the conclusions to be drawn from this investigation will be communicated at a later date to the Royal Geographical Society, when Dr. Cornish has completed the examination of the data he has obtained.

TUESDAY, AUGUST 6.

The following Papers and Reports were read:—

1. *An Expedition to Ruwenzori.* *By* R. B. Woosnam.[1]

The author began with a short itinerary of the Ruwenzori expedition from Mombasa to the West Coast of Africa, illustrated with photographs of Uganda, Ruwenzori, the Semliki Valley, the Congo Forest, and the Pygmies. He then proceeded to sketch the general features and life-zones of the Ruwenzori range, illustrating these by a diagram of the altitudes at which typical forms occur, and by photographs of the vegetation. He concluded with a short account of the distribution of birds and mammals on the mountain.

[1] The paper will be printed at length in the *Geographical Journal.*

2. *The Newly Discovered Cave of Atoyac (Mexico): A Contribution to the Study of Cave-development.* *By* M. M. ALLORGE, *L.es-Sc., F.G.S.*

Introduction.—When we follow the railway line from Vera Cruz to the City of Mexico we cross, first, a line of dunes behind which extends a swampy plain of Pleistocene sands. At a slightly higher level stands another plain of Pliocene age, built chiefly by the mud streams coming down from the neighbouring volcanic cones. After Passo del Macho we meet for the first time a longitudinal ridge of limestone, which is a spur of the Western Sierra Madre. This limestone contains a number of hippurites and rudistæ, establishing its Middle Cretaceous age. The railway runs over this limestone from the 80th kilometre across Orizaba as far as the 180th kilometre near the station of Esperanza, after which the country is completely covered by volcanic ejecta.

Upon this calcareous bed, sink-holes swallowing up rivers are of very frequent occurrence. The Spanish name for a funnel-shaped depression of this kind is *sumidero,* and one of the railway stations has been called by this name. These *sumideros* correspond to an extensive system of subterranean channels; the deepest are still used by underground streams, whereas the higher ones are mostly dry, and have reached a state of old age, characterised by the deposition of sinter and the formation of stalactites tending to obstruct them again. The cave of Atoyac is an instance of this class.

Location.—The mouth of the cave is located amidst steep slopes 900 metres east of the station at Atoyac, about 70 metres below the railway, and 26 metres above the present level of the river flowing at the bottom of the gorge. The opening was discovered during the summer of 1906 by Señor Sanchez when hunting big game among these precipices. During the following autumn the writer had an opportunity of visiting it with Professor C. de la Torre (Havana University), and of making a rapid survey of it. The entrance is partially closed by the fall of débris. The strike of the cretaceous limestone at this point is north to south, the dip is about 75 degrees east, and the jointing is approximately perpendicular to the strike. A glance at the plan of the cave shows that the succession of channels and chambers is not random, but presents a rectangular arrangement. The main passages run in a north to south direction, according to the strike; they may be called subsequent. They are connected by smaller transverse corridors corresponding to the joint planes and obsequent to the direction of the strata.

The features of the interior were briefly described and accounted for. A transverse corridor is partially closed by a high ridge which has been probably formed by the blocks of limestone falling from the roof, damming back the water and slowly covered by the sinter deposited by the cascade. Near the top of the cave is a series of narrow tortuous passages, recalling to the mind the worm of a still. They are superposed one above another, and suggest the progressive tunnelling down of the waters. All these narrow tunnels run to the bottom of a vertical shaft, which the writer was not able to explore; but a constant current of fresh air (temperature 20° Centigrade) gives evidence of a direct communication with the surface of the soil. It corresponds in all probability to a chimney by which the surface waters were formerly engulfed.

Conclusion.—A careful analysis of the succession of chambers composing the cave of Atoyac proves that the work of excavation of the limestone by the waters has been controlled, down to its most minute details, by the planes of bedding and by the system of joints and of fractures. Subterranean waters always take advantage of these natural planes of division in dissolving or in eroding calcareous rocks.

Up to the great dam, pottery has been found, and there is evidence of the utilisation of this cave by the Indians some five centuries ago. The situation is so favourable that it has probably been used as a rock shelter at a much earlier period. The author thinks that if the actual sinter floors were carefully removed, and methodical investigations conducted, they would lead to valuable additions to our knowledge of American pre-history. The proximity of a railway station would greatly facilitate this research.

3. *Second Report on Investigations in the Indian Ocean.*

See Reports, p. 351.

4. *Interim Report on Rainfall and Lake and River Discharge.*

See Reports, p. 353.

5. *Interim Report on the Oscillations of the Level of the Land in the Mediterranean Basin.*—See Reports, p. 350.

6. *A Traverse of Two unexplored Rivers of Labrador.* *By* Mrs. LEONIDAS HUBBARD, Junior.

The Labrador peninsula comprises that portion of British North America lying east of Hudson Bay and north of the Gulf of St. Lawrence. It is a vast rocky plateau, its slopes cut by valleys into which flow the waters of its thousands of lakes and streams in a mad rush to the sea.

The journey across the north-eastern portion of the peninsula by way of the Nascaupee and George Rivers was undertaken by Mrs. Hubbard for the purpose of completing the mission of exploration which in 1903 had cost her husband his life. She left North-west River Post, near the head of Lake Melville or Grosswater Bay, on June 27, 1905. Her crew numbered four; the outfit included two canoes and 750 lb. of provisions, with two rifles, three single-shot pistols, and one revolver. The first task was the tracing of the Nascaupee River to its source. The river descends from its source at the height of 1,675 feet above the sea, by what may be termed a series of steps. The larger part of the descent is by rapids, only a few falls occurring, and those of no great height. A comparison showed a drop of 1,600 feet in 137 miles in the case of the Nascaupee, but only 224 feet of fall in 113 miles in the swiftest part of the St. Lawrence.

Five weeks of struggle with the rapids found the party encamped on August 2 on the shores of Lake Michikaman, a great interior lake; and on August 10 the final source of the Nascaupee River on the Height of Land was reached. Here the travellers were in the midst of the caribou country. On August 8 a herd of some thousands was seen, and for fifty miles of the journey the country was alive with them, the beautiful creatures approaching sometimes to within 20 feet or 30 feet of the camp.

The source of the George River was located immediately beyond the Height of Land in Lake Hubbard. It is a tiny stream as it first steals away northward; but in the three hundred miles of its course it gathers force and volume till at its discharge into Ungava Bay it is a great river three miles in width. The upper part of each of the rivers consists of a series of lake expansions of varying sizes. Some sixty miles from its source the George River drops from the plain of the lakes through three narrow gorges, and thenceforward flows in a distinct valley.

Two bands of Indians were encountered, both of which received the travellers in a friendly manner. The first, who were of the Montagnais tribe, were camped on Resolution Lake, about fifty miles from the Height of Land. Only the women and children were there, the hunters having gone to the coast to trade for winter supplies. Fifty miles below, the Nascaupee camp was visited. These Indians are probably the least known and most primitive of the tribes of North America. Some were dressed entirely in deerskins.

The most thrilling part of the journey was the descent of the last 132 miles of the George River, where it flows in almost continuous rapids through country becoming more and more mountainous, rugged, and barren, till in the last fifty miles the banks become gradually lower as the river nears the sea. The journey of about six hundred miles was made in sixty-one days, the party arriving at the Hudson Bay Company's Post near Ungava Bay on August 27.

7. *Notes on British New Guinea.* *By* Dr. W. M. STRONG.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section.—Professor W. J. Ashley, M.A., M.Com.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

If I attempt what has been more than once undertaken by my predecessors in this Chair—a survey of the past history and present position of political economy in this country—there are circumstances, obvious to all, which render the task to-day far easier than before. The passage of time brings many advantages, the advantage, above all, of perspective. We are able to look back and make out the relative magnitude of things; we can see how the objects in the field of vision group themselves together; and the influences which are dubious when they surround us are no longer questionable when we can stand away from them and discern their beginnings and their endings. And thus it is that we can now say—and expect general acquiescence—what twenty years ago would have called forth loud protest, and would, indeed, have been premature; and that is, that the first phase of economics as a systematic study in this country is now well over; that the orthodox economics of the middle of the nineteenth century has for some time been quite dead. We shall differ, unquestionably, as to its value, both as an intellectual construction and as an instrument of social and political change; we shall differ, perhaps, as to the relation to it of that present-day teaching which some will deem a natural outgrowth from the old, others its very antithesis. But about the fact of its departure we shall all be agreed. No economist of any reputation in this country, or in America, or in Germany, when left to himself, lays stress now on the propositions which Ricardo and his school emphasised; nor does he draw the same conclusions as to practical policy. At most he may seek with natural piety to show how certain famous sentences, properly interpreted, may still be regarded as containing an element of truth. Every new text-book that appears makes the disappearance of the old orthodoxy the more evident; indeed, it is the very consciousness that the old has passed away which is bringing the present flood of new text-books upon us. And hence the position of the first phase of English economics as a system of thought has passed in large measure out of the sphere of the controversial; we can criticise it objectively and dispassionately; it has become a closed chapter in intellectual history.

It is the additional good fortune of those who would seek to disentangle the outlines of that chapter that the materials for that, as well as for preceding chapters, are now ready to their hands in a whole series of recent publications. Among those to whom we are especially indebted gratitude compels me to mention the names of Professor Oncken, Professor Hasbach, Dr. Cannan, Professor Foxwell, and M. Halévy. But there is one writer upon the so-called 'classical' economics whose recent masterly treatise has been peculiarly welcome; I refer to the late Sir Leslie Stephen's 'English Utilitarians.' And for this reason in particular, that Leslie Stephen was neither an historical, nor a reactionary, nor a socialist critic of *laisser-faire.* His sympathies were with the older economists rather

than against them; his general mental attitude was still so largely that of the utilitarian circle that he might be counted upon to do the Ricardians full justice. If anyone still doubts whether there really was such a thing as an orthodox body of economic doctrine, the doubt can be quickly resolved by reference to Leslie Stephen's pages.

Few things are more remarkable in the history of thought than the rapidity with which the Ricardian economics secured its dominion over public opinion. Adam Smith had laid the foundation in the assumption of free competition; Malthus had absolutely reversed the ideas of social philosophers on the subject of population. But neither in 1776 nor in 1798 was the man or the time ready for a 'system.' The creative period came a good deal later; it hardly extends beyond the decade from 1810 to 1820. Towards the end of that decade, in 1817, Ricardo's book rose above the torrent of controversial pamphlets, and almost at once the edifice was complete. The doctrine of rent which Ricardo championed furnished a centre round which the other doctrines could group themselves; while the conception of natural law—taken over by the Physiocrats long before from contemporary philosophy, learnt from the Physiocrats by J. B. Say, and now, through Say, impressed anew on Ricardo and his associates—gave to the new tenets a superhuman sanction. For if the word 'religion' has any meaning, we must recognise that political economy was, in a very real sense, one of the new religions of that wonderful era of fermentation. As early as 1821 the 'deposit' of doctrine was complete; it only remained to propagate it. And this completion of the system is indicated by two events. One was the foundation of the Political Economy Club; the other, the publication of James Mill's 'Elements.' The Political Economy Club was the assembly of the elders of the new Church, and its rules breathe all the spirit of ecclesiastical fervour. The 'just principles of political economy' are assumed to be already discovered; the members bind themselves to procure their 'diffusion.' They declare it to be their duty 'to watch carefully and to ascertain if any doctrines hostile to sound views on political economy have been propagated'; they undertake 'to avail themselves of every favourable opportunity for the publication of seasonable truths.' James Mill's manual is even more symptomatic of the stage which political economy was believed by its adepts to have reached. Political economy, it takes for granted, is already a 'science' whose 'essential principles' are known, and need only to be 'detached from extraneous topics' and 'stated in their logical order.' What shows, perhaps, best of all how completely all hesitation has passed away from the mind of its author is the fact that the work is avowedly designed to be a 'school-book,' addressed to 'persons of either sex of ordinary understanding'—the first, in fact, of those manuals by which young people have been turned into prigs before their time. And it was James Mill, we are coming more and more to realise, who did more than any other one man, first to impel Ricardo to write, and then to systematise the new faith and organise its propaganda.

How rapidly that propaganda was successful! In 1821 Ricardian political economy was the creed of a part only of 'a small and very unpopular sect,' the Utilitarians, which 'excited antipathy on all sides.' Its teaching, we may recall, was received with repugnance and protest by the man of that age who saw most deeply into the human soul—I mean, of course, Wordsworth—as well as by Coleridge, who was beginning to teach his countrymen a truer philosophy of history. And yet in another ten years it had won wide acceptance, and had become the dominant force in social legislation. What Coleridge said in 1832 of the Malthusian foundation was true by that time of the system generally; it had 'gotten complete possession of the leading men of the kingdom.'

It would occupy us too long, and it might suggest a controversy I should wish to avoid, if I sought to furnish a complete explanation of this remarkable and rapid success. We should probably all agree that the system owed its general acceptance less to its intellectual merits—for when have great political forces been set moving by sheer weight of argument?—than to its singular appropriateness to contemporary conditions. It appealed both to the good and to the evil

sides of the new manufacturing middle class; to the spirit of enterprise which no longer felt the need of the protective legislation of the past; and to the narrow self-satisfaction which found in the law of population a release from the sense of social obligation. The term 'manufacturing economists,' applied to the Ricardian group by a pamphleteer of the period, was eminently apposite; and as the manufacturing interest coalesced with the fragments of the old Whig connection, and formed the modern Liberal party, the new political economy furnished a platform on which both these wings could unite, and which saved them from the necessity of falling back for a policy on the more thorough-going democratic doctrines of un-'philosophical' or præ-'philosophical' Radicals and Chartists. That 'they overrated the political economists' is one of the chief reasons assigned by Dr. Arnold in 1840 for the difficulty he felt in working with the Liberal party; and it must be remembered that, in thus being taken over into practical politics political economy lost altogether the hypothetical character which its more cautious exponents attributed to it; its conclusions were no longer remembered to require 'verification'; 'other considerations besides the purely economic' were left to the other side to point out; and economic principles were regarded as rules directly and immediately applicable to existing circumstances.

It is not, however, any particular explanation of the very general acceptance of the Ricardian creed as early as 1832, but the bare fact of that acceptance that I wish to lay stress upon. Indications of it abound. Consider, for instance, the almost complete neglect which all contemporary economic writers suffered—and there were not a few—who diverged from the now codified teaching. We can understand this with writers like Thompson and Hodgskin, from whom Marx seems subsequently to have derived the claim for the labourer to 'the whole product' of industry. This was a doctrine for the manual workers, and their time had not yet come. But, as Professor Seligman has recently pointed out, there was also more than one writer of the period who anticipated what has quite recently become, for the time, the current teaching of most English-speaking economists. The marginal conception of value which this generation owes to Jevons and Menger was clearly enough expounded by Longfield in 1833, but it passed unregarded. As I am not myself altogether convinced that the notion really carries us any great distance, for reasons to which I shall return, I do not particularly blame his contemporaries. But it is evident that their inattention was due, not to dissatisfaction with what men like Longfield offered them, but to satisfaction with the apparently sufficient formulæ they had already mastered.

A further indication of the victory of the Ricardian school may be found in the promulgation of what may fairly be called the orthodox doctrine of economic method. The essay of the younger Mill 'On the Definition of Political Economy, and on the Method of Investigation proper to it' was drafted and completed in these very years of triumph—between 1829 and 1833. The proper method, according to John Mill, was the *à priori* one, 'the only method by which truth can possibly be attained in any department of the social science.' Though he then avoided the term 'deductive,' and continued to the end to use 'inductive and 'deductive' in a fashion of his own, 'deductive' is the fairest brief description of what he had in his mind, and he finally fell back upon the word in his 'Logic.' In the treatise of Cairnes on the subject, which may be regarded as an expansion and popularisation of Mill's essay one-and-twenty years later, it is clearly laid down that as 'the economist starts with a knowledge of ultimate causes' the preliminary work of induction to reach premisses is reduced to a minimum, and the economist must 'regard deduction as his principal resource.'

It cannot be necessary to examine the correctness of this opinion, for the simple reason that it is no longer entertained in all its primitive rigour and vigour by English-speaking economists, and it is held by few indeed of those of other countries. Professor Edgeworth, in reviewing some years ago the book of the Dutch economist Pierson, remarked that 'it is refreshing to find in these days a first-rate economist who has the courage to say that deduction is the only effective method'; and Pierson's singularity sufficiently indicates the present state of opinion. It would, indeed, be misleading to imply that all

serious workers in the economic field are absolutely at one in this respect. But since Henry Sidgwick's eminently judicial review of the controversy in 1883; since the leading representatives of opposing schools in Germany, Wagner and Schmoller, have approached each other so nearly in their recognition of the equal validity of induction and deduction for 'the tasks appropriate to each'; since the *doyen* of English economists, Professor Marshall, has come to use, with such hearty acquiescence, Schmoller's metaphor of the two feet equally necessary in walking—sweeping assertions like those of John Mill and Cairnes sound antiquated to our ears. Let me interpose the remark that a method of observation and generalisation—the method, in fact, of historical and statistical inquiry—is peculiarly appropriate to a kind of investigation which the older economists hardly contemplated, and that is into the structure of industrial organisation and institutions and the evolution of that structure. But for this process it is misleading to use the term 'induction,' since 'induction' suggests a different sort of goal. And, on the other hand, it would seem as if less use were being made of 'deduction' in recent years by abstract economists themselves. Certainly, in the various marginal theories of distribution which have been pushing the simple Ricardian tenets into the background, it is not so easy to disentangle a deductive line of reasoning as it was, for instance, in the earlier doctrine of wages or profit. The fashionable modern term 'analysis' is elastic enough to cover several different kinds of mental operation. 'No one who knows the meaning of terms,' we have lately been informed in a tone of authority, 'will call the analytical study of the motives which govern men in business a *strictly* deductive method.'

To return, however, to John Mill and the 'methodology' of 1833. Perhaps the most curious fact about it, when one comes to reflect, is its totally unhistorical character. Cairnes says somewhere that 'no economic or social truth meriting the name of scientific ever has been discovered' by induction. But it may be said with equal positiveness and more accuracy that none of the fundamental doctrines of Ricardian economics were actually discovered by deductive or *à priori* reasoning. As Professor Hasbach has so usefully reminded us, they were all of them conclusions directly suggested to observers by the facts of life before them—observers some of them in past centuries, some recent, like Anderson and West and Malthus. What the Ricardian group did was to work these 'truths' into a system and support them more or less by formal reasoning. Deduction became in their hands an effective pedagogical method, but it had not really been the instrument of 'discovery.'

Yet its unhistorical character only brings out more clearly the place of John Mill's doctrine of method in the history of economic thought. Its appearance marks the passage of the Ricardian faith into its third stage—the stage of apologetics; and apologetics, here as elsewhere, tended to mask and misrepresent the real character of the forces and influences which had actually given rise to the doctrine. Nevertheless for some decades it was sufficient for its purpose. When John Mill came to write his own great text-book in 1848 he 'spoke as one expounding an established system;' and established the system remained for at least twenty years longer. Fawcett's book, which appeared in 1863, which ran through many editions and remained the text-book for passmen well into the 'eighties,' was only a simplified Mill. During all this time orthodoxy was a very real thing, and the penalties of heresy were not always light. In the bitterness of his heart Jevons once declared in a private letter that 'the Mill faction never scrupled at putting their lecturers and examiners wherever they could.' But 'faction' is too harsh a word; it was the body of the Church.

That the doctrine should remain so long in vogue in academic, civil service and journalistic circles, in spite of the assaults of Mr. Ruskin and in spite of the just anger of the working classes, is easily explained. It was due chiefly to the success, for the time, of the great Free Trade measure of 1846; a measure which, though dictated by the immediate interests of the manufacturers, was in complete accord with the then orthodox economics. English trade was increasing 'by leaps and bounds'; England was becoming the workshop of the world, and seemed likely so to remain. The doubts which even men like Malthus, not to

mention conservative philosophers like Coleridge, had entertained as to whether a purely manufacturing policy would turn out in the long run to be safe could be contemptuously dismissed; and the literary dignity of John Mill's book did much to secure its hold on respectful attention. Those who were drawn to a more generous attitude towards the labouring population and a nobler conception of society than were congenial to the first generation of economists found much to appeal to them in the moving passages which Mill wrote under the influence of Comte and the Socialists. It was as yet hardly realised that such passages had no natural place in the body of orthodox teaching.

There were not wanting during this long period of half a century currents of European thought which might have been expected to disturb the complacency of English economics. But these currents never made their way into England. For the failure of each of them there is perhaps some explanation. Comte's criticism of political economy (1839–42) was associated with a destructive philosophy of religion, and with a personality singularly alien to any usual English type. That Le Play's method of family monographs and workmen's budgets should have had to wait to our days before it called forth imitation in England is harder to explain; but that may also have been due to the association of a method of economic investigation with a large philosophy of religion and society, very different from that of Comte, but, like Comte, speaking a dialect foreign to English ears. The creators of the German 'historical' school of economists—Roscher (1843), Hildebrand (1848), Knies (1853)—had no such associations to hamper them, and in their own country their influence quietly spread over the Universities and among the official classes. But the period was one marked in England by an almost complete ignorance of contemporary German thought. It was indeed the time of Germany's humiliation; and I suppose the victories of 1870 did more to make us learn German than any spontaneous enlargement of interests.

I began by saying that the Ricardian orthodoxy is, by general consent, to all intents and purposes dead to-day among English-speaking economists. By that, of course, I do not mean that there are not even yet portions of their writings that are still valuable; but that what the Ricardians themselves regarded as the most vital part, the part which they frequently identified with political economy as a whole, the part which lent itself to practical conclusions in the sphere of taxation—that is to say, the doctrine of distribution—is no longer held (with the dubious exception of the doctrine of rent) in any shape which they would themselves have recognised. Its abandonment has been due to a series of assaults from several quarters and on different parts of the fabric, which occupied little more than the decade 1870–80. They were all, immediately if not ultimately, from English directions; they were all, not from outside humanitarians, but from professed economists; and some of them were from men who had no sort of realisation of the damage they were doing to an edifice they supposed themselves to be propping up. It will be enough to mention them in order. In 1869 John Mill threw over his disciples and renounced the wage-fund doctrine, giving hardly a thought to the security of what remained. In 1871 Jevons produced his quasi-mathematical theory, the effect of which was to show, as he declared, how 'that able but wrong-headed man David Ricardo shunted the car of economic science on to a wrong line, a line on which it was further urged towards confusion by his equally able and wrong-headed admirer John Stuart Mill.' In 1874 Cairnes 'newly expounded' 'some leading principles of political economy' in a way which, while 'not in any sense antagonistic towards the science built up by the labours of Adam Smith, Malthus, Ricardo, and Mill,' aimed at showing that, 'as at present generally received,' it contained 'no small proportion of faulty material.' In 1876 Bagehot began a series of articles which were intended to rehabilitate orthodox economics—among other ways by returning to the narrowness of its scope before the younger Mill tried in vain to widen it, but with the result, in many minds, of still further discrediting it. In 1877 the American economist Francis Walker produced a new and far-reaching doctrine of wages. In 1879 Cliffe Leslie's collected essays introduced the English reader

to the German historical economists, and made clear—what the consistent advocates of a 'hypothetical' science had never denied, but what ordinary economic writings had been curiously unable to keep before men's minds—the vast difference between 'tendencies' and actual phenomena. And finally, in 1881–2, the lectures of Arnold Toynbee made an attempt to show how the historical method could be applied to the interpretation of actual conditions. Meanwhile, it should also be added, the dissemination of the teachings of the so-called '*scientific*' socialists—of Lassalle's 'Iron Law of Wages,' and of Marx's 'Surplus Value'—disposed conservatively minded thinkers to re-examine that Ricardian teaching to which the Socialists, with so much show of reason, were in the habit of appealing.

To what now has all this ferment led? After a time of almost complete chaos it might seem as if a new structure of theory with regard to the fundamental problem of distribution has once more been erected—to judge from the appearance in these latter years of a whole shelf full of imposing text-books. We need but glance through them to discover that there has as yet been no substantial reconstruction among English-speaking economists on *historical* lines. The historical study of economic conditions has, it is true, made considerable progress; to that I shall return later. But the centre of interest among academic economists (and with them must be reckoned for this purpose some influential writers outside the Universities) is still to be found, both in this country and in America, in abstract argument. Among the diverse lines of thought which converged upon the old orthodoxy for its destruction in 1870–80, that represented by Jevons has for the time had the widest influence. It has been supplemented by the similar influences of Austrian economists—Menger, Böhm-Bawerk, and Wieser—who have been made accessible to English readers by translation or paraphrase; and partly under impulses from Jevons and the Austrians, partly from an original turn for abstract speculation, there has appeared in America an independent theorician of the first rank, Professor Clark, who has already carried most of the younger economists of the United States with him, and is beginning to make himself felt on this side of the ocean.

In speaking of this second, this newer, phase of abstract economics, my task is more perilous. The movement has only just got well under way; and it would be rash to predict its destination. I shall confine myself to a very few observations; and possibly one who occupies a detached position outside theoretic discussion may see some of the larger features of the situation more distinctly than those who are themselves taking part in the debate.

Perhaps the best term for the representatives of the newer abstract phase would be 'the Marginalists.' They employ the conception in different ways and with different results; but with all of them the notion of the *Margin*, the *Grenz*, is a never-failing resource. They all begin, at any rate, by laying stress on the doctrine of marginal or final utility, some as the key to the whole problem of value, some as the key to the demand side of it. And what has one to say to it? Of course, in the first place, it is quite true, so far as it goes; and, in the second place, it is pedagogically of some use. It puts an elementary bit of psychology in a way calculated to make the youthful beginner do a little thinking. Even for this purpose it is not without its dangers; for 'utility' cannot but be a constantly misleading name for mere 'desiredness,' however carefully it may be explained. Suppose, however, we all remember always that 'utility' does not necessarily mean in economics what it means in ordinary speech, how far does the doctrine take us? I cannot help thinking that it takes us a very short way indeed. Instead of leading us to the very heart of the problem, the doctrine of marginal value seems to me to remain entirely on the surface; it is not much more than a verbal description of the superficial facts at a particular point of time. The intensity of demand varies inversely, more or less rapidly, with the extent to which it is satisfied; for different commodities there are different scales of intensity; under certain circumstances one demand will be substituted for another. True, doubtless. But *why* do people demand just those things? On what does the rapidity of satiation depend? Have their desires always been the same; or the possibilities

of production in order to meet them? How are desires related to one another? What are they likely to become? What are the limits to demand set by the economic situation of the demanders? These are the things we really want to know. The problem is, in a wide sense of the term, an *historical* one; or, if you prefer the phrase, a *sociological* one, both 'static' and 'dynamic.' Behind the workman's wife making up her mind on Saturday night whether to buy another loaf or a scrap more meat stand the whole of human nature and the whole of social history. And this is what, I suspect, the deeper thinkers among the Marginalists are obscurely realising. When Professor Marshall distinguishes between normal and market value, and invites us, in order to understand normal value, to contemplate a chain of forces operating, both on the demand and the supply side, for indefinitely long periods, is he not in substance recognising that the problem is one of age-long development? And, similarly, when Professor Clark points out that even utility is not a homogeneous thing; that every commodity is really a bundle of utilities for different purposes; and that therefore 'value is a *social* phenomenon,' he is approaching the real complexity of a sociological problem. It is with a true instinct that Mr. Carver waives these subtleties of the Columbia economist on one side; he perceives that simplicity of economic 'analysis' would speedily disappear if the psychology became more profound.

When we pass from marginal utility to the exposition of the laws of distribution to which it serves as a prelude, the attempt to judge of the true character of the neo-abstract literature of recent days becomes extraordinarily difficult. For one who should try, as I have recently done, to review that literature as a whole will be startled to find how far-reaching are the divergences within it. Its only unity would seem to consist in a common belief in the value of abstract (or, as it is sometimes called, 'general') reasoning, and in the common employment of a few specialised terms. Doubtless all the differences could be construed as differences of emphasis; but this is hardly reassuring, for the emphasis may differ so much as to give totally opposite impressions. A man may be 'coloured' with so little emphasis as to be practically white, or with so much emphasis as to be practically black. So long as the student keeps to a particular set of writings, he may cherish the impression of a triumphant analysis, solving all difficulties for intelligent men in the same way; when he extends his reading he will find that there are at least three main groups, following respectively the lead of Cambridge, of Vienna, and of New York; while among the younger men there are all sorts of ingenious but mutually irreconcilable attempts at eclectic compromise.

The want of agreement shows itself, I cannot help thinking, even before we turn to specific doctrines, when we ask ourselves what is supposed to be the relation of the several 'systems' to real life. It is the old difficulty, still giving trouble, of the relative importance of 'tendency' and 'friction.' Grant, if you will, the possibility of a doctrine of tendencies, it is surely of the first importance that we should have a pretty definite and continuous impression as to the width of the gap between the formulæ and visible phenomena. Yet, while some of the abstract economists give the impression that the tendencies they formulate are actually, with some little delay and in a rough-and-ready way, on the whole realising themselves in concrete circumstances, others give the impression that their science is so very 'pure' as to have hardly anything visibly in common with the crude doings of impure humanity. One leading writer assures us that in his book 'normal action is taken to be that which may be expected, under certain conditions, from the members of an industrial group; and no attempt is made to exclude the influence of any motives, the action of which is regular, merely because they are altruistic.' On the other hand, his persuasive American colleague turns our thoughts in just the opposite direction. He tells us that 'the impression of unreality which is made by the studies of the classical political economy is removed by completing them on the same theoretical plan on which they have been started. We must use assumptions boldly and advisedly, make labour and capital absolutely mobile, and let competition work in ideal perfection.'

There has been one fresh and welcome advance upon the position of the older writers. Both Professor Marshall and Professor Clark would seem to agree in

describing their methods of treating economic phenomena as primarily 'statical,' even if they are not quite at one in the meaning they attach to the adjective. Both regard a statical doctrine as, in a sense, only an introduction, though a necessary one in their eyes, to 'a more philosophic treatment of society.' It is not, indeed, easy to see how a whole abstract system can be made an essential preliminary; if, as the former writer tells us, 'the function of analysis and deduction in economics is not to forge a few long chains of reasoning, but to forge rightly many short chains and single connecting-links'—a place which all sensible historic economists would readily grant to it. However, the distinction between static and dynamic is a significant precaution, if only the ordinary reader can bear it in mind. If 'actual society is always dynamic,' and 'because of this continual evolution the standards of wages and of interest to-day are not what they will be ten years hence,' it is evident that the lonely figure of 'the marginal shepherd' would give little help in settling, let us say, the Australian shearers' strike. And this, perhaps, is why a younger American economist already referred to, who retains the old orthodox preference for a short way with dissenters, becomes a little restive. 'The static state,' he says, is 'a heroic assumption of doubtful utility.' Possibly he fears that, if the appearance of the promised 'dynamic' theory is long delayed, the assumption may be as dangerous as some other 'heroic' remedies have been.

Until that time comes, and looking only at the several 'static' systems themselves, we find that there is hardly a single point in the whole theory of distribution on which there is as yet any approach to unanimity. What was the one doctrine associated with the name of Ricardo which survived the wreck of 1870–1880? It was the so-called 'Ricardian' doctrine of the rent of land. Most British economists cling to the conception still, and regard the distinction between land and other instruments of production as one of the first importance. Indeed, they have gone further, and have applied the marginal idea and the term 'rent' to all surpluses derived from the possession of differential advantages. It then becomes natural to see 'quasi-rent' or 'analogies to rent' in every direction. But, from seeing a peculiar thing everywhere, the transition is easy to seeing no peculiarity anywhere. And thus it is not only the Austrian writers who are disposed to rub out the distinction between land and other instruments of production; the chief American theorist, Professor Clark, throws the whole Ricardian doctrine overboard. He is daring enough to say that the arguments advanced to prove that 'rent does not enter into price' would 'prove that wages and interest are also residual amounts, having no price-making power; and this is an absurdity.' A growing band of American disciples accepts this view; and in recent text-books, like those of Professors Fetter and Seligman, the beginner is calmly told that the doctrine still taught by high authority in England 'is now being abandoned by economic students.'

The same contention reaches our ears when we approach any other part of the field of distribution. What, for instance, is profit? Is it a return for the business man's share in the work of production? Is it a marginal product? Or does it arise because the owners of the real 'factors of production' do not succeed in getting *their* 'marginal products'? Is there, after all, *normally* no absolute net profit (*Unternehmergewinn*) apart from interest, wages, and insurance? On all these points discord reigns among what would seem to be equally competent theorists. Or take interest. What is the explanation of the fact of interest? Large Austrian books have been translated which dismiss all previous explanations with contempt, and instruct us that the true solution is the discounting of future goods. This view, which our leading English economist condemns as 'one-sided,' has, nevertheless, found some acceptance in England, and it is accepted wholesale in the Dutch treatise which has been recently translated for our benefit because of its unique combination of reasoning power with knowledge of affairs. If there were time we could take the remaining topic of distribution, viz., wages, and entangle ourselves in the like perplexity. It may be enough if we notice in passing that, on such a vital question as whether trade-unions could effect a general rise of wages, not only would opinions differ, but those who agreed in their answers would get at them in quite different ways.

It has not been my purpose in thus displaying the present position of abstract economics to deny its interest. Its study is certainly sharpening to the wits, and it is hardly likely that all the opposing doctrines are mistaken. It may be that in another quarter of a century opinions will have shaken themselves down and assumed their permanent places and proportions, and then the 'system' to which we shall have arrived may be of evident assistance in the understanding of life. Meanwhile, an Englishman may feel a just satisfaction in the width of sympathies and the sober balance of judgment which marks the chief English treatise of this period, and even an untheoretical reader will gratefully acknowledge the abundant help to be derived from Professor Marshall's knowledge and insight. My purpose was simply to show that, though there has been a new growth of abstract speculation since the first phase of orthodoxy passed away, there has not emerged a second orthodoxy so far. There is no reason why those who think that a very moderate amount of general reasoning will go a long way in the interpretation of facts, when once these facts have been collected and arranged, should be so dazzled by any of the new systems as to be checked in their own more plodding career.

Side by side, however, with all this activity in the field of theory—an activity which, it must be confessed, has almost monopolised the attention of professed economists—there has been a most remarkable awakening of interest in the actual economic history of our land. As I have already observed, the criticisms of the historical school have not led, so far, to the creation of a new political economy on historical lines; even in Germany it is only within very recent years that some of the larger outlines of such an economics have begun to loom up before us in the great treatise of Gustav Schmoller. But what has, at any rate, been secured in this country is a most substantial increase in the knowledge of our own economic past. How remarkable the progress has been we only realise when we begin to look back and take stock of our recent acquisitions. Five-and-twenty years ago interest in the subject was curiously languid. This had not always been the case. In the eighteenth century Anderson and Eden had brought together great collections of material; and in the thirties and forties of last century the currency discussion had produced the work of Tooke, and pride in the new inventions a number of histories of particular trades. The most typical book of this later period, however, was the work of Ricardo's brother-in-law, the first head of the Statistical Department of the Board of Trade. Porter's 'Progress of the Nation' (1836–1843) was a prolonged statistical pæan of triumph over the results of growing enlightenment. The blessings of the new era having thus been displayed, it might seem as if it was hardly worth while to learn anything more about the past. If a student had inquired in 1880 for the best recent treatises dealing with our economic history at large, he would have been referred to Leone Levi's 'History of British Commerce' from 1763, and to the first two volumes of Thorold Rogers' 'History of Agriculture and Prices,' coming down to 1400. The former was a useful compilation put together in the most unscientific and philistine spirit; the latter was the outcome of a vast amount of toil, but the material collected was not of such a nature as to afford a clear understanding of the fundamental institutions of the Middle Ages. Accordingly, those who began to interest themselves in such subjects were compelled to look abroad. In the works of Brentano, Ochenkowski, Schanz, Nasse, and Held they found, in varying degrees, a scientific method and a stimulus not to be met with at home; and there can be little wonder if they were inclined to assign to one or other of these German monographs more weight than really belonged to it.

But the years 1882–1884 marked the beginning of a better time. Three books appeared, very different in their character, but each in its way opening a new era. To Toynbee's 'Industrial Revolution' (1884) I have already referred. Its chief value lay in its showing how impartial investigation of the past could be combined with ardent enthusiasm for social improvement. Shortly before, Dr. Cunningham's 'Growth of English History and Commerce' (1882) had given us for the first time a treatise which attempted to cover the whole historical ground. It was the forerunner of those enlarged and rewritten editions which have grown into the three stately volumes now on our shelves.

The time would fail me to single out the numerous particular topics on which Dr. Cunningham has enlightened us; what is a far greater service is that by his masterly and encyclopædic grasp of the whole vast field he has kept before our minds the fundamental idea of the continuity of our national development. About the same date the book of Mr. Seebohm on 'The English Village Community' (1883) gave us, for the first time, the right starting-point for our study of mediæval (and therefore of modern) agrarian history. It is an example of the way in which even the largest facts of national life are apt to drift out of the minds of the next generation that the 'open-field' system of husbandry should have been entirely forgotten in hardly more than fifty years from the time when the thing itself finally passed away. The manorial economy, as Mr. Seebohm reconstructed it, may possibly be a little more symmetrical than the facts; but, without an understanding of its main features, mediæval agricultural conditions must have remained unknown to us. Let anyone who fails to appreciate Mr. Seebohm's incomparable services try to find in any modern writer before him a clear explanation of the *yardland*—the pivot of the agricultural organisation of every old English village.

Of subsequent workers in this field of economic history it is only possible to give a bare list. Professor Maitland, whose untimely loss we all deplore, has enabled us to get truer notions of mediæval law: he has confirmed the impression that there were certain underlying conditions common to the whole of Western Europe by his proof of the acceptance of the canon law in England; and to his example and influence we owe a great increase in the printed materials for manorial and municipal history. Mr. Powell has added exactness to our knowledge of the great peasant rising; Mr. Leadam has printed the official evidence concerning the enclosures of the sixteenth century; Mr. Stevens, Sir George Birdwood, and others have given like assistance for the beginnings of our East India trade; Miss Leonard has explained the part played by the earlier Stuarts in establishing the English poor law; Mr. Galton and Mr. Unwin have helped to bridge over the gulf between the mediæval guild and the modern trade-union; Mr. and Mrs. Webb have laid bare the local government of the seventeenth and eighteenth centuries, a period more obscure in some ways than the age of the Plantagenets; Mr. Gray has written the annals of philanthropy; and Mr. Slater has taken up the thread of agrarian history and systematically examined the later enclosures. The beginnings of Scotch manufactures have been explored by Mr. Scott; the troublesome story of the relation of English policy to Irish industry has been told by Miss Murray; the history of nineteenth-century factory legislation has for the first time been written in perspective by Miss Hutchins and Miss Harrison conjointly; the movement of wages during the same period has been traced by Mr. Bowley; and while the modern combination of labour has found its first serious historians in Mr. and Mrs. Webb, the even more recent tendency towards capitalist combination has been portrayed by Mr. Macrosty. For particular industries we have now the works of Mr. Ellison and Professor Chapman on the cotton trade, and Mr. Jeans' reports on the iron trade; while Dr. Creighton has dealt with a subject of the utmost economic interest in his history of epidemics. This is a recital of which we may well be proud.

And meanwhile we have been receiving assistance equally valuable from foreign scholars. Two American students trained in Germany—Messrs. Page and Gay—have thrown a strong light on the commutation of labour services in the fourteenth century and on the enclosures of the sixteenth and seventeenth. Two German scholars, Professor Ehrenberg and Dr. Lohmann, have greatly added to our knowledge of the place occupied in our history by the woollen industry, the one explaining the struggle for the admission of English cloth to the Continent, the other the methods of governmental regulation. Two others, Professor Hasbach and Dr. Levy, have turned their attention to our agrarian development; and, while the former has investigated the fortunes of the agricultural labourer, the latter has traced the rise and decline of capitalist cereal farming. And it is a sign of the recent revival of solid historical studies in the land of M. Fustel de Coulanges that a French scholar, M. Mantoux, has just given us by far the most complete account of the industrial revolution of the

eighteenth century. If we cannot but regret that some of these books do not bear the names of English scholars, there still remains a large field for English scholars to explore.

Accompanying the new zeal in this country for original research, there has come a recognition equally new of the importance of economic history in the examination requirements of the Universities. On looking at the fresh work of investigation which we have just been surveying, it will be observed that a large part of it has been more or less closely connected either with Cambridge or with the London School of Economics; and it is notorious that the impulse has been due in the one place chiefly to Dr. Cunningham and in the other chiefly to Professor Hewins and Mr. Webb. Accordingly, it is appropriate that economic history should have been given a respectable place alike in the Cambridge History Tripos and in the examination for Science Degrees in Economics in the University of London. Even more significant is the room made for economic history in the Economics paper of the First Class Civil Service Examination, both for home and for Indian appointments. Quite a considerable number of undergraduates do now every year give some little attention to the subject; at least half a dozen formal examination papers must be set upon it annually; and there are already three or four elementary text-books in existence for the beginner to choose from. And all this is so far to the good; in an examination-ridden country it is the only way in which a subject can command any general attention. But I seem to observe a certain tendency towards what I should regard as an unfortunately sharp division for academic purposes between economic theory and economic history. There is an inclination to regard each as a specialism unconcerned with the other; represented by different experts; or, if sometimes combined in one person, kept in separate compartments of the brain. It is inevitable and salutary that some economists should be much more historical, others much more theoretic, in their interests. But a complete divorce either of narrative history and description from the large consideration of cause and effect or of pure theory from the conception of historic evolution would seem to be equally undesirable.

I have not concealed my opinion that much of the labour that has been devoted to economics in English-speaking countries during the last quarter of a century has been less fruitful than one could desire, and yet the outlook is more encouraging in many respects than ever before—certainly in this country. For look at one interesting feature of the present situation. It is only of late years that the teaching of economics has begun to be so recognised and organised in our universities that it can be said to offer a career to a young man of ability in the sense in which, for instance, chemistry offers a career.

The triumph of the Ricardians led to the creation of professorships of political economy at Oxford in 1825, at Cambridge in 1828, at Dublin in 1832. The two rival London colleges, University and King's, and the Queen's Colleges in Ireland, followed suit. But until a surprisingly recent date there was no real working professorship of political economy in Great Britain comparable to the ordinary professorships in any German university—and by 'comparable' I mean carrying with it a living wage and involving the devotion of the main strength of the incumbent to the duties of the chair. The remuneration was in most cases absurdly inadequate; the appointment at Oxford and Cambridge was the sport of election, and was at first made for a term of years; and it was commonly regarded either as a stepping-stone to a Government appointment or as an appendage and assistance to a political career. This was due partly to the place which professorial lectures generally then occupied in university life. 'Professors' lectures were considered to be mainly ornamental, and they scarcely formed a part of the real educational system.' It was due in part to the then orthodox view of the character of the study. 'According to Fawcett,' says Sir Leslie Stephen, diplomatically, in the life of his friend, 'the leading principles of political economy and those which were really valuable were few, simple, and therefore capable of an exposition on the level of average intelligence.' And the same view was held by most of his contemporaries, both here and in America. The author of the best-known American handbook of economics of this period has

himself described his scientific equipment: 'I had scarcely read a dozen pages of Bastiat when, closing the book, and giving myself to an hour's reflection, the field of political economy in all its outlines and landmarks lay before my mind.' In those days the presidency of an American college was commonly given to an elderly clergyman, and in the choice of teaching duties to be attached to the office the lot usually fell upon political economy, because it was the easiest subject to get up.

But to return to Great Britain. It was not till Professor Marshall became professor at Cambridge twenty-two years ago that either of the older English universities secured in its chair of economics an effective head of a living department of university study. Meanwhile, certainly, things had been improving elsewhere. At Owens College a chair had been created—or rather a half-chair, for political economy was joined with logic—and it had been made the most of by Jevons; and in 1871 another was founded at Edinburgh. After 1871 followed a long interval, devoid of addition to the scanty number of economic chairs. In the middle of the eighties, however, came a fresh moving of the waters: first ill-paid lecturerships made their appearance; and then these gradually blossomed out into full professorships. Toronto led the way within the Empire in 1888; Liverpool and Glasgow established professorships in 1891 and 1896; and since then Birmingham, Manchester, Leeds, and Bristol, as well as Montreal across the sea, have followed the example. The other universities and university colleges are, with few exceptions, already in the lecturer stage. The professor, where there is one, is also usually assisted by a lecturer; two or three graduate scholarships have already been created to assist the future economist in his earlier steps; and in the 'Economic Journal,' so impartially edited by Professor Edgeworth, as well as in the 'Economic Review,' both founded in 1891, there is a medium for the publication of scholarly, non-popular work. Economics, in short, is beginning to furnish a career.

This is a condition of things in itself favourable to economic studies. It has its drawbacks indeed, and I feel personally and painfully enough the dangers of academic life. We must all be aware how much we owe to writers unhampered by the duties of the professional teacher of economics—to men like Mr. Seebohm, Mr. Booth, Mr. Rowntree, Mr. Palgrave, Mr. Webb, Mr. Hobson, Mr. Money, and Mr. Welsford, to mention but a few among them. But such non-academic work involves either the possession of private means or the pursuit of some other and remunerative occupation, such as journalism. And grateful as we must be for all original and stimulating contributions to knowledge, we cannot be so confident, either in the supply of men of means with scholarly interests or in the ability of journalists to overcome partisan predilection, as to dispense willingly with a reasonably large contingent of professed economists within the Universities.

The revival of economic studies in Great Britain of late years has been due to the almost unconscious convergence of several influences. On the one side has been the growing interest in what are called 'social questions,' and, combined with this, a perception of the need for more systematic training for that work of municipal and political administration which is every day embracing a larger part of the national activity. It is to motives like these that was due the foundation of the London School of Economics. Too much credit can scarcely be given to those who, whatever their own economic views, had the statesmanlike courage to found an institution distinguished from the first by the largest impartiality, or to the first director, Mr. Hewins, who conducted it through the difficult years of its infancy. Coming from another side there has been a realisation of the need for systematic training for commercial careers—the conviction to which have been due the new Faculties of Commerce at Birmingham and Manchester, and the new Economics Tripos at Cambridge. On this aspect of the recent development, which naturally is to me of primary interest, I shall make only one comment—that I am convinced that the study of actual business organisation, methods, and conditions is not only desirable for the preparation of our future leaders of trade and industry for their subsequent careers; though when we consider all that that means we can hardly over-estimate its importance. It is desirable also for the enlargement and

deepening of the purely scientific understanding of economic problems. To take but one example, the investigation of the modes of life of the working classes which we owe to Mr. Booth, to Mr. Rowntree, and more lately to Lady Bell, will have little meaning unless we can combine it with a study of the situation from the other end, from the end of the director of business operations, and can see how his policy is shaped, and how it affects the workpeople.

May I add one concluding observation, and that not, I hope, in an unduly controversial spirit? When one looks back on a century of economic teaching and writing, the chief lesson should, I feel, be one of caution and modesty, and especially when we approach the burning issues of our own day. We economists—for, whether we like it or not, we of to-day have to bear the sins of our predecessors—we economists have been so often in the wrong! On so very much that had to do with the condition of the great body of the people we were for half a century either so glaringly mistaken or so annoyingly unsympathetic that even to-day a man is ashamed to avow himself an economist in the face of an English working-class audience. And on questions of trade, how hasty, how superficial, seem now many of the opinions so confidently expressed by our predecessors in the days of England's 'industrial supremacy.' In the present position of economic theory, moreover, there is everything to deter us from dogmatism. There are, it is true, a few elementary propositions on which all who have given any systematic attention to the subject are agreed; but they are so very few, and they carry us such a little way! In various directions in economic literature we can find patches of systematised fact and little bits of general reasoning which deserve attention. The outlines, moreover, of our industrial history are beginning to be unveiled. But there is not yet—perhaps there never will be—a body of generally accepted economic doctrine by which every practical proposal can at once be tested. As Professor Marshall has truly said, 'the science is still almost in its infancy.' Surely we have learnt that the time for sweeping generalities has gone by.

'In the world in which we live'—the same writer has remarked with regard to the fundamental question of value—'every plain and simple doctrine . . . is necessarily false, and the greater the appearance of lucidity which is given to it by skilful exposition the more mischievous it is.' And what is true of the foundation is true of the superstructure. Among serious economists there is hardly one left who would maintain that theory is capable of furnishing a conclusive proof either of the wisdom or the unwisdom of free trade under all circumstances. Nothing is easier than to adduce a number of theoretic arguments on either side. The right decision in each case must be reached, not by abstract reasoning, but by estimating the concrete facts and probabilities which give the several arguments their due weight. What the Cambridge economist has pointed out so forcibly a few months ago with regard to economics at large is applicable equally to this particular topic. 'There is a general agreement as to the character and directions of the changes which various economic forces *tend* to produce. . . . Much less progress has been made towards the *quantitative* determination of the *relative strength* of different economic forces.' And this, he confesses, is the 'higher and more difficult task.' Meanwhile, it behoves each of us to make it clear that, even if he is speaking *ex cathedrâ*, as people say, he is still speaking *in propriâ personâ*, with all his limitations and unconscious bias; he is not the mouthpiece of Science.

I venture to lay stress upon this point, because I am most anxious that economists—not as exponents of a unanimous doctrine, but as individuals who have given time and thought to industrial and commercial affairs—should have their just share in guiding national action in the future. In 1840 John Mill startled his utilitarian friends by the remark: 'The spirit of philosophy in England is rootedly sectarian,' and in 'philosophy' he included economics. We have seen how the Ricardian school, the first phase of economic orthodoxy, was in fact an appendage to the Liberal party of those days. It would be regrettable if an impression grew up to-day that economists still gave up to party what was meant for mankind. I recognise, of course, that the economist's present attitude must be affected by his forecast of the future. If he thinks that all departure from the present commercial policy of this country is likely to be permanently staved

off, then the preservation of a future influence is not an object worth considering. But there must be many who, as they look around them and reflect upon what other democracies have done in our own time, will confess that change is probable, much as they may at present be inclined to regret it. And, if so, must they not desire that the measures on which the country may embark should receive as much competent criticism in detail as can possibly be directed upon them? I have always recognised that the strongest argument against a policy of preference is that it may open the door to forms of protection that are unnecessary and undesirable. Only a grave sense of the needs of the nation and empire could induce any of us to be ready to face the risk. But the risk could be, and ought to be, minimised by the pressure of competent and well-informed criticism of particular measures. The excesses of protection, both in the United States and in France, have been due, in no small degree, to the extreme doctrinaire attitude of American and French economists, an attitude so extreme that the busy, practical world went on its way as though they were not. Let us hope that this country will profit by the warning, and that her economists will not be put out of court at the outset by the justifiable ascription to them from either side of a disqualifying bias.

The following Papers were then read:—

1. *A Suggestion for a new Economic Arithmetic.* *By* Professor T. N. Carver, *Ph.D.*

How to make the study of economics of greater value in private as well as in public affairs is a problem of increasing importance, now that University men are turning more and more towards business careers.

Something may be done by giving more attention to economic history and to commercial geography and statistics, but reliance must be placed mainly upon economic theory, which need not consist in deduction or *à priori* reasoning, but simply in the analytical study of the observations and experiences of our common everyday life. The object of this analysis is to trace the relations of cause and effect among the economic phenomena around us. But how to make the results of this analysis a part of the mental equipment of the future man of affairs is a difficult problem. The writer believes that the method of setting problems to be worked out by simple arithmetic, problems based upon well-known economic laws, and requiring careful analytical thinking on the part of the student, will help to solve the difficulty. Agriculture furnishes simpler problems than any other industry, but the method is applicable to all.

The following table, with the problems based upon it, will serve to illustrate the method:—

Quantity of corn grown with varying quantities of labour on a given quantity of land.

Number of days' labour of a man and team with the appropriate tools	Product, in bushels, of each of four fields of ten acres each			
	Field A	Field B	Field C	Field D
5	50	45	40	35
10	150	140	130	125
15	270	255	240	220
20	380	360	300	270
25	450	420	350	310
30	510	470	390	340
35	560	510	420	360
40	600	540	440	375
45	630	560	450	385
50	650	575	455	390

The following problems are based upon the above table:—

Problem 1.—Assuming that the labour of a man and team, with the appropriate tools, costs a farmer 20*s*. a day, and that corn is worth 1*s*. 6*d*. a bushel, how many days of such labour could he most profitably devote to the cultivation of each of the four fields, assuming that they are all the land which he has at his disposal?

How would the problem be affected if labour cost 10*s*. a day instead of 20*s*.?

Problem 2.—Assuming that the farmer has 200 days' labour, and no more, which he can devote to corn growing, but that he can have, rent free, an indefinite quantity of land of the grade of field A, how many acres could he most profitably make use of for corn growing?

How would the problem be affected if he had to pay a rental of 30*s*. an acre?

Problem 3.—Assuming that the two fields A and C belong to the same farmer, and that he has but 20 days' labour which he can devote to their cultivation, how could these 20 days be most profitably distributed between them? How could 25 days be most profitably distributed? 35 days? 50 days? 60 days? 70 days? 90 days?

Problem 4.—Assuming that the relation of the labour-supply to the land-supply is such that 130 days' labour, of the kind assumed in the table, will seek employment upon the four fields A, B, C, and D, what would be the normal rate of wages, *i.e.*, what is the highest rate at which the farmers would find it to their advantage to employ the entire labour-supply—corn being worth 1*s*. 6*d*. a bushel? What would be the normal rental of each field?

How would wages and rent be affected if the labour-supply were 170 days instead of 130?

Advantages of this method:—

1. A test of the clearness of the student's understanding of economic principles and therefore an antidote against slipshod thinking.
2. It furnishes the future man of affairs with formulæ to which he may profitably adapt his system of accounting.
3. More comprehensible, though less compact, than algebraic or trigonometric formulæ.
4. It places certain questions beyond the field of controversy.

2. *The Laws of Increasing and Decreasing Returns in Production and Consumption. By* Professor S. J. Chapman, *M.A.*, *M.Com.*

The expressions '*law* of increasing returns' and '*law* of diminishing returns' are very loosely used. The author aimed at giving definiteness to these conceptions, and inquired whether on *à priori* grounds such laws can be predicated of actual conditions, that is, realistically and not merely in a highly abstract sense, and, further, whether analogous tendencies operate in consumption.

First it was pointed out that the field of production, whether industrial or agricultural, is organised in a hierarchy of diverse systems which may be classified into three orders corresponding to 'the business,' 'the industry,' and 'the community.'

The argument proceeded by deduction from the abstract laws of increasing and diminishing returns. The former may be represented as a law of specialism, and runs: *As a factor in production which is capable of specialising is increased its productive power is increased.* It is found that when it is phrased merely in this general fashion no law of diminishing returns can be predicated realistically on deductive grounds. Further inquiry shows, however, that a clause may be added to the effect that *the return in productivity of a specialisable factor in response to its increase must be subject at some stage to diminishing returns and ultimately become insignificant.* The abstract law of diminishing returns calls for little-discussion. It is enunciated as follows: *If the part of a group of factors which yield a*

product is increased, the other part remaining constant and no improved specialism resulting, the produce will increase, and at a diminishing rate after a time, and will finally diminish.

From these abstract laws it may be deduced that productive systems of the first order (*i.e.*, individual businesses) must in their partial and total growth become finally subject to decreasing returns; that systems of the second order (*i.e.*, industries) are subject to increasing returns as regards total expansion, and must ultimately fall under diminishing returns as regards partial expansion; that the generalities in question predicable of systems of the second order hold also of those of the third, *i.e.*, of communities as a whole.

Attention being directed to the problem of consumption, it was indicated that things are demanded as well as produced in systems of different orders, and that within these analogous laws may be laid down, though they do not actually correspond to those of production.

FRIDAY, AUGUST 2.

The following Papers were read:—

1. *The Rise and Tendencies of German Transatlantic Enterprise.* *By* Professor Ernst von Halle, *Ph.D.*

There was no German traffic beyond the seas to speak of before the formation of the United States. The consequent disruption of the Colonial system produced lively trade-relations during the ensuing period of French revolutionary wars. After a short interruption, produced by the 'continental system,' a second impetus was given by the establishment of other independent States in South and Central America, 1815–1830. The abolition of the Colonial system in the rest of the European Colonies marks the third phase of expansion; and the opening of trade relations with Eastern Asia, commercial treaties with Japan and China, mark the fourth. Preceding the formation of the German Empire there existed a very limited commerce with Australasia and Africa. By 1871 German tradesmen and bankers, particularly sons of the Hanseatic towns, were to be found in all parts of the world.

A few German merchant princes and a larger number of small tradesmen abroad not only maintained relations with their country, but also handled the traffic of other commercial nations.

London was the money market, and to some extent the money-lender. On the other hand, a large share of German Transatlantic exports and imports passed through English warehouses, and more still in English bottoms. The political decentralisation of the country had for centuries left the majority of German States without seaports and seafaring interests. The Zollverein brought commercial unity to the interior and Baltic sections, but did not embrace the North Sea ports till after the three wars which gave the Empire a flag and a commercial policy.

At this time the population, which had doubled since 1800, numbered 42,000,000. In the next thirty years 20,000,000 more were added; 65,000,000 live to-day where about 20,000,000 lived at the close of the Napoleonic wars. Besides the increasing population, three events—the opening of the grain-fields in North America, the introduction of iron and steel steamers into the Transatlantic freight service, and the rise of large industries in Germany after the war—were the chief cause of the country's transition from a grain-exporting nation into a grain-importing nation by the middle of the seventies. The industrial crisis increased the protectionist tendencies among the manufacturers, while American competition turned the agriculturists to protectionism. But the new economic policy did not stand in the way of rapidly increasing imports, which had to be paid for by increasing exports.

It was not the manufacturing interests of the capitalist that nourished exports,

but rather the demand of a growing population for food-supplies and industrial opportunities of employment. Up to this time Transatlantic enterprise had been of a somewhat incidental significance for German national economic life: it now became vital. Larger exports of merchandise and capital for foreign investment, the establishment of large commercial fleets, insurance and cable companies, now became necessary to meet the increasing requirements of the importing interests. By inaugurating a Colonial policy in 1884 Bismarck meant to crown the process of empire-making.

The censuses of 1882 and 1895 show a remarkable transformation in the economic structure of Germany. Unable to employ a larger number of people in its pursuits, agriculture had thrown the full surplus population into industrial occupations. The agricultural classes in 1895 numbered about 18,000,000, about the same as a hundred years ago, whilst the industrial population had increased 600 per cent. The standard of life had improved throughout, chiefly in the middle and lower classes. In spite of the introduction of scientific methods, agriculture was unable to keep pace with requirements.

By 1900 one-fifth to one-fourth of the foodstuffs, and more than nine-tenths of the raw material for clothing, &c., had to be imported. Had not a rapid development of foreign trade and rising foreign investments closely followed the resulting necessities, either starvation, or emigration, or foreign war would have resulted.

To avoid a precipitated industrialisation and a dangerous decline of agriculture, the country decided upon an increase of agricultural protection. Germany's geographical position will always necessitate an ample agricultural resource at home to avoid the dangers of starvation in war times. She was compelled to sacrifice some of the industrial possibilities of tariff-treaties to this point of view.

The situation to-day is that Germany's foreign commerce amounts to 750,000,000*l.*, of which 425,000,000*l.* are imports.

Of the difference, fifteen to twenty millions are made up in the earnings of German shipping, the rest in the interest from foreign investment, consisting of 450,000,000*l.* investments in trans-oceanic countries, 800,000,000*l.* foreign stocks and bonds (of which more than 100,000,000*l.* is trans-oceanic), and more than 250,000,000*l.* other investments.

Of the imports, about 40 per cent. come from over the sea outside of Europe, while of the exports a little less than 25 per cent. go to foreign continents, more than 30 per cent. of its trade.

With neighbouring countries Germany exchanges more than 40 per cent.

The trade with the United Kingdom amounts to about 20 per cent. of exportation and 14 per cent. of the importation, and with the British Empire 24 per cent. of exportation and 22 per cent. of importation. While England has ceased to be paramount in German and foreign trade, it still holds the first rank. Of the commerce of the world, incoming and outgoing, the three leading countries, England, Germany, and the United States, to-day control the greater part in either direction. Of this a large share is transacted among these three countries.

German exports have not increased as rapidly as the demand for imports. The foreign investments are rising in importance. They may become the leading feature by the time that machine-using industries have become more extended in tropical and sub-tropical countries. Germany will have to improve her commercial and industrial processes, her means of transportation, and her business organisation to keep pace with foreign competition. The real dangers of the competition of the future are neither to be found in England nor in Germany, nor even in the United States, though this latter country makes a more rapid progress than the two former. They will ensue from the working of certain natural laws: increasing populations, increasing demand for the products subject to diminishing returns, and increasing supplies of the products subject to increasing returns.

The political tasks of Germany's future are continental, in consequence of its central position, and will continue to centre on the mainland of Europe, though her economic tasks will necessarily consist of a gradual extension of every form of her commercial sea-interests.

2. *The Labour Legislation of the Australasian States.* *By* J. Ramsay MacDonald, *M.P.*

Labour legislation in Australasia has been characterised by attempts to fix a minimum wage by statute, or by arbitration courts and wages boards; and as proposals are being made to adopt the same legislation here, I propose to discuss the circumstances under which the Australasian experiments are carried on and the economic possibilities of their success.

The arbitration courts originated in a desire to prevent strikes, and the wages boards in a determination to prevent sweating; but their evolution has been on the same lines. The workmen have used them as a means of distributing national production favourably for the wage-earners. In the working out of this, a national policy, know as the 'New Protection,' has been inaugurated, which, in its completeness, means: (1) Protection against imports by tariff; (2) a settlement of wages by boards and courts; (3) a fixing of prices by boards and courts; and, ultimately, (4) the securing to the home producer a first claim upon home-produced raw material, *e.g.*, wool and hides. This is the logical and inevitable result of any attempt to solve labour problems by compulsory trade-unionism, or by fixing a standard nominal wage by statutory decision.

The chief interest in these experiments lies in the attempt that is being made by them to secure a national standard wage, for the tendency of both courts and boards is to go beyond a minimum—strictly speaking. The New Zealand experiment proves, however, that where there is no agreement—and there can be none—as to what is an absolute standard, machinery created to settle a nominal standard from time to time will simply necessitate constant demands being made for an increase in wages. Such a thing is futile, and must break down.[1] A national standard wage is a chimera.

The New Zealand Arbitration Act has been more effective in organising the masters than the workmen, and it has therefore raised prices and rents. This I found to be pretty generally admitted, and is borne out by statistics.

The Victorian Wages Boards affect only certain trades, and their influence upon prices is obscure. They seem to have improved the character of the work done. Nominally, they only level up to recognised standards, but practically they try to do more; and the workers do not accept that limitation. Their effect upon sweating has been exaggerated, but they have been working under conditions which would yield to them a maximum beneficial result, *e.g.*, small number of workpeople affected, a market on the rise, &c. The statistics supplied are not fully satisfactory, and no thoroughly scientific examination has yet been made on the spot regarding the actual effects of the boards. Coghlan's analysis of wages shows their effects to be only very moderate. My own inquiries led me to the conclusion that they could be applied with comparative ease under factory conditions, with some difficulty under home-work conditions, and hardly at all under sweating conditions.

Even if we agree with what I can only regard as the altogether overdrawn praise given to Australasian labour legislation by some writers, we must remember, in considering how we can apply it to our own country, the industrial differences between us and these Colonies. Particularly (1) the opportunities which a protective tariff gives to increase nominal wages without increasing the workers' share of the national production; (2) the small industrial population, and the simple industrial constitution of the Colonies which permit them to try many experiments, and elude for a long time what is finally to be failure; (3) the fact that the Australasian industrial problem is limited and simplified by the consideration that production is as yet practically exclusively for the home market; (4) the greater opportunities of apparent success given to such courts and boards by the greater willingness of the Colonial mind to act generously to the worker, *e.g.*, courts and boards have been known to award the most extraordinary jumps in nominal wages which no judge or arbitrator would ever think of awarding here.

[1] *Cf.* the Dunedin Seamen's dispute; the resolutions passed by the Annual Trades and Labour Conferences of New Zealand; the attacks upon Mr. Justice Chapman, President of the Court.

3. *Sweating and Legislation.* *By* L. G. Chiozza Money, *M.P.*

Defining sweating as 'a condition of employment in which, through any or all of the following factors, (*a*) low rates of remuneration, (*b*) excessive hours of labour, or (*c*) unhealthy workplaces, the workers are unable to sustain physical efficiency,' existing legislation touching on these three heads is briefly as follows:—

1. *Wages.—It is at present perfectly legal to sweat by under-payment.* The method of payment of wages is in part controlled by existing legislation, but home-workers have practically no protection under the Truck Acts.

2. *Hours of Labour.*—There has been legislative interference with the hours of females, of young persons, and of children; but home-workers, not being within the scope of the Factory Act, are not subject to regulation in respect of hours.

3. *Environment during Labour.*—The Factory and Public Health Acts regulate the conditions under which work is carried on. The Factory Act, which imposes conditions as to cubic air-space, ventilation, &c., has little application to home-workers. In practice the home-worker is subject to little more than the provisions of the Public Health Act.

Summing up existing labour legislation, while it is found to be timid in many respects, even in its application to factory, workshops, laundries, mines, &c., it has little or no application to the home-worker. Thus the tendency of existing legislation is to put a premium upon home-work.

Proposals for legislation on the subject of sweating are next considered.

1. *To Make all Workplaces Legal 'Workshops.'*—This proposal seeks to make an employer as liable for the condition of the home of the outworker as he is for his own factory or workshop.

2. *To Register and License Outworkers.*—This proposal seeks to prevent work being done under insanitary conditions. It provides that it shall be illegal to give out work save to a licensed person.

The foregoing proposals do not touch the question of remuneration. The next deals solely with the wages question.

3. *To Establish Wages Boards.*—This proposal is to establish wages boards, on the lines of those in existence in Victoria, to control wages in the sweated trades by arranging minimum rates either for piece or time work. If adopted it would be the first act of legislative interference with rates of remuneration. It stands or falls with the principle of the minimum wage.

The conclusions submitted are:—

That sweating is a widespread evil which endangers at once the physical life and the industrial strength of the nation.

That the question of under-payment demands the recognition and adoption of the principle of the minimum wage.

That the further questions of excessive hours of labour and unhealthy environment during labour demand the drastic strengthening of labour law and its application to all workplaces, large and small, without exception.

That it is advisable entirely to prohibit the giving out of home-work to middle-

MONDAY, AUGUST 5.

The following Papers and Report were read:—

1. *Small Occupying Ownerships.* *By the* Right Hon. Jesse Collings, *M.P.*

The British land system, namely, that of landlord, farmer, and labourer—which meant three separate castes—has broken down in every other country in Europe,

has broken down in Ireland, and is breaking down in England. To it is mainly due our startling rural depopulation. Whilst there was an increase of 12·17 per cent. in the total population of England and Wales at the last census, the dwellers in the rural districts had fallen to less than $7\frac{1}{2}$ millions, or to 23 per cent. only of the whole population.

Those who urge that we must rely on trade and commerce for our prosperity are reminded that the greatest wealth of a nation is its producing power, and that, whilst the producing powers of many other undertakings are becoming more and more difficult, those of the land are not half-developed.

The conclusions urged are:—

(1) That the policy of placing trade and manufactures above agriculture is a wrong one.

(2) That an amount of capital (including the personal labour of the cultivating owner and his family) properly invested in land yields a far greater return to the community than a similar amount invested in commerce and manufactures.

(3) That, if health, physical strength, and an increase of the population are to be reckoned as national assets, agriculture enriches the nation far more than manufactures can.

(4) That the home trade, resulting from the development of agriculture, is larger, more certain, less fickle, and more valuable than the foreign trade.

Agriculture must not be regarded simply as any other trade, but as the basis of all trades. In France, Germany, and other Continental countries a prosperous agriculture and a consequent numerous and thriving rural population are regarded by statesmen as the two great pillars of the State on which the general well-being of the people rests. They are regarded as the true sources of wealth, as the most effective means to secure a wider distribution of wealth, and as the best guarantees for national stability.

Leaving the larger branches of agriculture—the raising of corn, cattle, &c.—and turning to 'small cultivation,' we observe that we annually import some sixty million pounds' worth of the smaller articles of food, such as butter, cheese, bacon, eggs, poultry, fruit, vegetables, &c., and that these articles might be wholly or mainly produced at home if our land system were what it ought to be.

We have the land, and we have the men standing idle or only partially employed. Many country-bred men now employed in the towns would gladly return to the villages (for which they are better fitted) if adequate and reasonable facilities were offered to them.

As to the land, inquiries show that in Great Britain there are some ten to twelve million acres of permanent grass (apart from the land used for hay, rich meadow land, and land unsuitable for the plough) which could be used by small cultivating owners, and this acreage is annually increasing. These ten to twelve million acres of uncultivated land are for the most part a national loss, and on them profitable employment could be found for at least a million of families, growing produce for which there is an almost unlimited demand.

To bring the men and land together is the work of the State, acting through a central department as well as through the local authorities.

Where small ownerships have been tried in this country, under the Small Holdings Act, 1892, they have been eminently successful: cases in point are the small holdings in Worcestershire created by the Council of that county. That Act, however, requires amendment, and some attempts were made by the author this year to get it amended, but they were resisted by the Government.

These proposals are only a part of a complete scheme for re-creating a peasant proprietary and yeomen freeholders. Attention is called to a Bill (No. 99) before Parliament this year, entitled the 'Purchase of Land (England and Wales) Bill,' under which it is proposed (1) that present farm-tenants shall be able to purchase the freehold of their land on agreement with their landlords or on its coming into the market, and (2) that the Board of Agriculture shall be enabled to purchase land for 'small holdings' for persons who desire to buy, and who will themselves cultivate such holdings. The principle of the Bill is the same as that of the Irish Land

Act, 1903. If necessary, all the purchase money is to be advanced by the State to the farmer, to be repaid—interest and sinking fund—by annual instalments. The Bill contains provisions against mortgaging, subdivision, and sub-letting, and thus the occupier is safeguarded from these admitted evils, to which all owners are often subject.

It is not contemplated that all the land should pass into the hands of cultivating owners—every kind of tenure would no doubt remain—but that 'occupying ownerships' ought to be the governing principle of our land system instead of being a mere incident in it.

To facilitate the carrying-out of the suggested scheme of small occupying ownerships, the author strongly advocates: (1) a better system of rural education, and (2) the establishment of co-operation among the cultivators both for the purposes of buying and of selling. But it is pointed out that co-operation is the natural outcome of small ownerships, but is not readily adopted by yearly tenants, who are often here to-day and gone to-morrow. In conclusion it is claimed that the suggested scheme as a whole would go far to solve the grave social problems of the day—the problems of the 'unemployed,' 'housing,' 'widespread destitution,' &c.—and that to pledge the national credit for the purpose of carrying it out would be in accordance with the principles of a sound national and political economy.

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2. *The Importance of the Distinction between* (1) *Subsistence Farming and* (2) *Producing for a Market, in connection with Small Holdings. By* W. CUNNINGHAM, *D.D., F.B.A.*

The competition of American agriculture, since the Civil War came to an end and the West has been opened up, has been felt very generally throughout Europe, and has threatened the rural system in many places by spoiling the markets. Agriculture as carried on up to 1860 has ceased to pay, and the local producer has great difficulty in getting a remunerative price. The difficulty has appeared in different forms in France, Germany, Austria, and Sweden, and has been met in various ways; but wherever agriculture is unremunerative it is likely to decline, with consequent depopulation of rural districts.

The magic of property cannot be relied upon to render land remunerative, or we should not find such numbers of derelict farms in the New England states. The sense of property is a stimulus to a certain extent, both to the investment of capital and to assiduity in labour, but it is in no sense magical. Tillage is not likely to be rendered more remunerative in England unless something new is adopted—new crops, new modes of tillage or of marketing; and the small holder has neither the capital nor the enterprise to embark in such undertakings; his forte lies in doing with assiduity that which his father did before him, or that which he sees his neighbour do. There is little reason to believe that great changes either in the crops or methods of English agriculture will be initiated by a cultivating peasantry, or that they will render it more remunerative.

Instead of invoking magical aid, we may learn from contemporary experience that it is sometimes possible to evade American competition; there are markets for the produce of poultry farms and dairy farms, for flowers, fruit, and vegetables, where local producers may hold their own. It is to be noticed, however, that the small holder, who lives by raising and selling such produce and has no other means of support, may be very severely hit, if not wholly ruined, by a single bad season; and that in any case he is at a disadvantage in regard to marketing as compared with the man who deals in large quantities.

If we look to the experience of the past we may find a suggestion as to another method of utilising the land that evades alike the influence of American competition and the economic difficulties which beset the small holder who farms for a market. The yeoman and the artificer in the Middle Ages farmed for their subsistence or to supplement their subsistence. If allotments and small holdings can be combined with opportunities of wage-earning, so that the land is used to eke out subsistence, the labouring population will be placed in a position of far

greater stability and will have greatly increased interests in life. This is being borne in mind in Sweden, where the movement for an increase of small holdings—to be farmed for subsistence—is going on side by side with the movement for increased employment in connection with forestry. Where the same kinds of crops are grown on small holdings and on large farms, there is of course greater difficulty in combining work for subsistence and opportunities of employment in rural districts. In towns, however, the facilities of communication render it much easier than in former days to provide artisans with allotment gardens, and thus to reïntroduce the system by which the manufacturing population could rely on what they themselves raised from the soil for a portion of their subsistence. Nothing would make more for the welfare of artisan families than to increase facilities of this sort, which give a double means of support and a wider range of common interests.

3. *Some Notes on the Small Holdings of Worcestershire.* *By* Professor Kirkaldy, *M.Com.*

The county of Worcester is a pioneer in the application of both the Allotments and Small Holdings Acts.

1. *Sketch of what has been done.*

(1) The Allotments Acts, 1887 and 1890.
(2) The Small Holdings Act, 1892.

The demand which led the County Council to take action was due to a peculiarity of changing conditions affecting the population of North Worcestershire. The application of machinery to the small trades connected with iron and steel has thrown many people out of work. These people have striven against fate, and legislation has provided a way of escape.

First experiment by the Council—the Woodrow estate at Catshill, 150 acres in extent. Purchase price, including timber, about 33*l.* per acre.

Points to note here: (i) Suitability of the soil for spade cultivation; (ii) proximity to a good market. Estate divided into thirty-two holdings, averaging $4\frac{1}{2}$ acres. Initial expenses, 287*l.* 14*s.* 7*d.*, added to the purchase price; then a margin allowed for contingencies. Sale price about 42*l.* per acre.

The scheme was not only advertised, but discussions and lectures arranged, so as to give the utmost publicity to the project.

Of the accepted applicants for tenancy about half were able to pay the 20 per cent. deposit required by the Act, and were at once registered as owners. The others were treated as tenants until they complied with this condition.

The half-yearly instalments are worked out on a four per cent. basis, spread over forty years.

Housing.—Different customs obtain in different localities, *e.g.*, at Catshill 'holders' as a rule build a cottage on their land; in South Worcestershire 'holders' prefer to live in a town and go out to their land.

If he wishes to build, a 'holder' can only borrow money for the purpose from the County Council. Hence the Worcester County Council has approved a special scheme to this end. Briefly this is that, certain conditions being complied with, the Council will advance on the security of the land 75 per cent. of the cost of a cottage and outbuildings. N.B.—The tenant's 25 per cent. may be chiefly made up of the expense of hauling materials (in his own cart) to the spot.

2. *Methods of Working.*

These for the most part are primitive. There is no co-operation or even mutual helpfulness among 'holders.' Hence are found uneconomic methods, such as overlapping, wasteful prices paid for seeds, &c., and an unwillingness to listen to experts.

In a word, the 'holders' are for the most part typical ignorant conservative

countrymen, suspicious alike of each other and of anyone inquiring into things. There are some bright exceptions to this.

The result of the above is the necessity for small holdings to be near a good market, so that each 'holder' can cart in his own produce.

The tools used are primitive, mostly spade and fork. There is no attempt at joint ownership of labour-saving tools.

Experience in the Evesham Valley: The sons, as a rule, do not wish to leave the land. A beginning is made as gardener's boy or labourer; then an acre of allotment will be taken and cultivated in off time. The life is hard but pays, and eventually the labourer-allotment 'holder' becomes the tenant of three or four acres of market-garden land, and can do well if he be hard-working and thrifty.

3. *Assessment.*

A thorny subject, but one to tackle. Instances of hardship:—

(i) Land before being divided up was, as part of a farm land, rated at about 19*s.* per acre; on being divided up in 1892 assessment was raised to 25*s.*, the farm being left at 19*s.* In 1905 the assessment put up to 40*s.*, but on appeal fixed at 30*s.*, the farm remaining at 19*s.* Immediately land is added to any of these holdings now the assessment is raised to 30*s.* before any profit is made or improvements effected.

(ii) [In a different locality.] Land originally assessed at 30*s.* on becoming holdings was raised to 55*s.* before any profits were made.

(iii) Instance of a farm assessed on land and good buildings at 40*s.*: local expert told of adjoining holdings, similar land without buildings, assessed at 62*s.* 6*d.* and 65*s.*

4. *Summary.*

(i) Small holdings movement is in its infancy; much has yet to be learned.

(ii) The Worcestershire experiments show value of a committee of practical men keen for the success of the scheme.

(iii) The small holder is not found ready-made; he must learn his business.

(iv) The application of co-operative methods would probably admit of a very extensive development of small holdings throughout the country.

(v) The French and German methods might be studied with advantage.

(vi) Small holders should take advantage of the help of science.

(vii) The question of assessment requires thorough overhauling.

4. *Agricultural Co-operation in Great Britain.* *By* R. A. Yerburgh.

The problems to be solved are the limitation of the rural exodus and the rehabilitation of rural life.

The economic aspect of the problem is how to make farming pay on a small as well as on a large scale. The economic forces at work against the farmer are the competition of new countries, made possible by the development of cheap transport, and the competition of older countries in which an agricultural revival has taken place. In the latter case, co-operation has been one of the chief factors in the success of our competitors. By its means farmers are enabled to obtain goods of guaranteed quality and purity; to purchase their requirements more cheaply, and so to decrease the cost of production; to bulk the consignments of goods purchased and goods sold, and so to reduce the cost of transport; to get into closer touch with the consumer, and so to secure a larger share of the profit upon goods sold; to place large quantities of produce of uniform quality upon the market, and so to meet the requirements of a wider circle of customers and to obtain better prices.

Co-operation has other advantages which should commend it to us. Among them are the development of character and of the intellect. Farmers as a class are intensely conservative, wedded to the ways of their forbears and jealous and

mistrustful of one another. Intercourse at the meetings of their societies tends to break down the barriers of mistrust and jealousy which separate farmer from farmer, to broaden their outlook, and to teach them no longer to regard the welfare of their neighbours as detrimental to their own; while the discussions upon business matters have a stimulating effect upon their minds and arouse a spirit of inquiry and a desire for knowledge.

While there are instances of agricultural co-operation in Great Britain of many years' standing, there was no systematic effort to promote it until the Agricultural Organisation Society was formed in 1901. It is true that co-operation was part of the programme of the National Agricultural Union, of which Lord Winchilsea was the founder and the inspiring spirit, but it was never seriously taken in hand. In 1900, in addition to the N.A.U., another body had come into existence to promote agricultural co-operation, viz., the British Agricultural Organisation Society. To prevent waste of force it was decided to amalgamate the two and to form them into a society on the lines of the Irish Agricultural Organisation Society. This was done and the results obtained have been eminently satisfactory.

The number of agricultural co-operative societies affiliated to the Agricultural Organisation Society had reached 153 at the end of June 1907. These included 109 societies for the purchase of requirements and sale of produce, 14 dairy societies, 13 credit societies, 4 allotment societies, 2 motor-service societies, 2 fruit-grading societies, 7 miscellaneous societies, and 2 federations.

The membership of the societies in June 1907 was roughly estimated to be 10,000, and their turnover in 1907 is expected to reach 450,000*l.*

The material benefits to the members of the societies have been considerable, but it is impossible to estimate them with any accuracy. In the purchase of requirements they have secured reductions in price averaging probably about 15 per cent., and the benefit of obtaining goods of guaranteed purity is fully equal, if not superior, to that of the reduction in price. The sale of produce has not been developed to the same extent as the purchase of requirements, but where it has been carried out the net prices to the farmers have been substantially increased.

There has been ample evidence of educational as well as material results. It is the experience of the societies that co-operation has produced a more neighbourly feeling amongst the farmers, who become more ready to interchange ideas and place their knowledge at each other's disposal. With this has come a greater desire for knowledge.

An important form of co-operation is co-operative credit. Village banks on the Raiffeisen model were promoted by the Co-operative Banks Association before the formation of the Agricultural Organisation Society. In 1903 the two associations were amalgamated. In June 1907 there were thirteen village banks affiliated to the Agricultural Organisation Society. The object of these little banks is to provide their members with capital for reproductive purposes at low rates of interest. A Central Co-operative Agricultural Bank has been formed for the purpose of financing the village banks.

For the success of the small holdings system co-operation is essential. Without it the small holder is at the mercy of the middlemen from whom he purchases his requirements and to whom he sells his produce. Co-operation places the small holder on an equal footing with the large farmer in his dealings, and provides him with the use of cheap loans for economic and productive purposes.

The intense conservatism of the farmer makes the work of organisation very difficult. His naturally suspicious temperament adds to the difficulty, as he is apt to imagine that those who are urging him to co-operate have an axe to grind in doing so. Gradually the Agricultural Organisation Society has been able to remove this suspicion from the farmers' minds, and the success of the co-operative societies is breaking down their disinclination to adopt new methods.

The chief difficulty which now confronts the Agricultural Co-operative Movement is that of obtaining the necessary funds for carrying on propagandist work. The Agricultural Organisation Society feels that it may reasonably look to the

Government for assistance. The Small Holdings Committee recommended that the Society should receive a grant from the Board of Agriculture, and in the Small Holdings and Allotments Bill the importance of agricultural co-operation in the development of small holdings is recognised. In Ireland the Department of Agriculture makes a grant to the Irish Agricultural Organisation Society proportionate to the subscriptions which it receives from other sources, and it would greatly help to foster the movement in Great Britain if the Board of Agriculture would make a similar grant to the Agricultural Organisation Society.

5. *Some Considerations about Interest.* *By* Professor E. C. K. Gonner, *M.A.*

The main groundwork of interest. Causes for its existence under present social conditions.

Two theories alleged in respect of its connection with accumulation and the provision of capital. These advanced to justify it as a branch of remuneration. These theories canvassed and points of difference indicated. Their interaction if both are operative.

The second theory considered in more detail and with particular reference to two points: (*a*) The extent to which saving under interest by one generation renders unnecessary saving by subsequent generations. In this case a decrease in the net capital thus provided by one generation, should interest vanish, may be wholly or largely compensated for by more general saving; (*b*) the extent to which the elimination or even the great decrease of interest involves the growth of insurance. The general growth of insurance.

6. *Interim Report on the Amount of Gold Coinage in Circulation in the United Kingdom.* See Reports, p. 353.

7. *Index Numbers of Prices.* *By* Professor A. W. Flux, *M.A.*

The paper called attention to some defects of the ordinary methods of constructing index numbers, as illustrated by such numbers as that of Sauerbeck. A formally unweighted average becomes in course of time effectively weighted. Thus in 1904 the index number for Java sugar was 40, that for Straits tin 121. In 1905 these became 45 and 136 respectively. Equal percentage changes do not affect the aggregate equally. Tin is practically weighted three times as heavily as sugar.

In other index numbers, such as Bradstreet's, the weighting employed is peculiar; yet the results correspond fairly with those of other authorities, in accordance with the general results of the Committee of this Section, which dealt with the matter some twenty years ago.

A method which continually reverts to equal weighting seems worth trying. By determining each year the percentage change of price from the preceding year for each of the commodities dealt with, and averaging the result, we have the material for building up a continuous index number free from some inherent defects of the method of the fixed-reference period. Some results of applying this process to the data used by the Bureau of Labour of Washington, U.S.A., were given. About 260 commodities contribute to this index number.

When proceeding by this method the geometric mean of the items is submitted to be more appropriate than the arithmetic. The actual results over the period 1890–1905, sixteen years, are very close to those obtained by the reference-period method, with an arithmetic mean, in the Bureau Index.

Attention was also called to the probability that the study of the grouping of the index numbers of individual commodities about their mean may yield valuable results. The standard deviations of the groupings of the year-to-year price-indices

were quoted as varying between about 11 and 17 per cent. during the period studied. It was suggestsd, in conclusion, that the measurement of the extent of the average change in prices over any prolonged period cannot be done with great precision.

TUESDAY, AUGUST 6.

The following Papers were read:—

1. *Co-operation.* *By* C. R. FAY, *B.A.*

In a sense we are all co-operators, just as in a sense we are all Socialists. Without 'co-operation,' without, *i.e.*, the organisation and interchange of services, human activity is ineffective. But co-operation in its technical sense signifies a peculiar organisation of business activity. As a trading body, the co-operative society differs from the trade union, which is organised for collective bargaining and friendly benefits, and from the friendly society or mutual insurance society (la Mutualité), which make provision among their members for occasional accidents and periodic needs. The co-operative society is essentially a trading body, but, as distinct from the joint-stock company, it is a union of persons knit together by a common need rather than by a material capital, and prepared to grant the profits of membership to all those who perform its duties, in proportion to the loyalty with which they make use of the society. Co-operation is, in effect, the means whereby in the last fifty years or more over the continent of Europe generally the weaker members of the population have successfully assumed certain functions of organisation and management, hitherto ineffectively or harshly performed by independent parties. Co-operation may be organised from the standpoint of the producer, both in the country and in the town.

The rural credit-bank provides the producing farmer with capital, just as the supply society supplies him with his raw materials, and the machine-owning society with the use of machines. These societies, together with the different forms of productive societies, dairies, distilleries, wine societies, bacon societies, societies for the sale of corn, vegetables, or fruit, have made the small cultivator the business equal of the big farmer and the townsman.

The counterpart of the rural productive society in the town is the labour co-partnership, as it is called in England. In the labour co-partnership, the working members are organised in a single business concern, whether it be a boot and shoe society, such as flourishes in England; or a society of builders, such as in France; or a labour (*i.e.*, navvy) society, such as in Italy. They are not independent producers and do not therefore require supply societies or credit banks like the farmers. In Germany, where the town credit-banks flourish, there are practically no labour co-partnerships. The two are in a measure opposed. The former tend to keep the small independent producer small and independent, their chief active members being small artisans and shopkeepers; the latter assemble their workers under one roof and try to educate them up to the delicate task of conducting a modern business in the double rôle of employers and employed. The labour co-partnership obviously makes very severe demands on the character of the worker, and it is unlikely in the future to be a common industrial type. But its organisation has, in England especially, roused employers to imitate its methods by introducing into their businesses schemes of profit-sharing and representation of workers.

Co-operation may also be organised from the standpoint of the consumer. This is the form which predominates in Great Britain as the 'store,' and which, as first established by the Rochdale Pioneers, has been faithfully and consciously imitated by almost every country of Europe.

The Association of Consumers is uninterested in the occupation of its members as such, since it exists to provide them with the necessaries of life as cheaply and efficiently as possible. It begins in the store with retail distribution; it then goes one stage back to wholesale distribution; and finally to large scale produc-

tion. This is what Great Britain through its wholesale organisations in Manchester and Glasgow has done; and this is precisely what other nations are in process of doing. Great Britain took the lead, because it was the first to possess, as the result of the industrial revolution, a distinct working-class, which proceeded to organise itself as wage-earners in a trade-union and as wage-spenders in a co-operative store.

Three problems at present confront the stores in Great Britain:—

(1) The relation between the stores and the land.

In Denmark and Switzerland, the peasant proprietors in addition to their productive associations have also their own retail and wholesale stores. In Great Britain the farmers are only just beginning to co-operate for production, and the agricultural labourers are almost totally unorganised. Is it desirable that the stores should own productive establishments on the land? The erection of creameries in Ireland by the two British wholesales has been resisted on the ground that it obstructs co-operation among the resident farmers as producers. Further, is it probable that the inhabitants of the land, whether farmers or labourers, will become in large numbers members of the stores, most of which are recruited from the towns? This is partially realised in some districts of England, where the farmers and labourers sell their produce to the store and take provisions in exchange.

(2) The relations between the retail stores and the wholesale.

In Great Britain the hold of the wholesale on the stores has tightened with the growth of the movement. By what means, therefore, can the strength of unified organisation be retained without a sacrifice of that democratic freshness which marked the self-sprung and self-directed work of the early pioneers?

(3) The attitude of the store-movement towards Socialism.

If the stores mingle in politics, they may degenerate into mere party instruments. If on the other hand they confine themselves to strictly business operations, there is greater danger of their becoming a working-class aristocracy, looking askance at their poorer and more undisciplined brethren. How far will this ever-growing army of organised co-operators, comprising already the *élite* of the working classes, be able to win the lower strata of working men and women without modifying that strict neutrality in politics and religion which has hitherto distinguished the store-movement in Great Britain?

2. *Co-operative Production from the Labour Co-partnership Standpoint.* *By* Amos Mann.

The principles of labour co-partnership in production are, briefly, that every worker should have the opportunity of becoming a partner in the concern in which he is employed, and should share in the development, control, and direction of the business. In the co-operative movement there are two schools of thought, represented by the English Co-operative Wholesale Society, called the Federal system, on the one hand, and the Labour Co-partnership Association on the other. In the former system co-operative distribution societies join together to produce the articles they need. In their workshop employees occupy the same position as they do in any ordinary workshop. The results of such trading are given back in dividends to the shareholding societies. The worker, as a worker, has no share in the profits or responsibilities, as is the case in what are called independent productive societies. These are composed of shareholding societies and individuals; every worker is allowed—and in some instances obliged—to become a shareholder in the society; a fixed portion of the profits is paid to the workers, and they share in the responsibility and control of the business by voting for the committee of management, and in many cases have seats upon the directorate. The author claimed that this latter system comes

close home to the worker, making him take a greater interest in his work and bringing forth the best results of his labour. In order to show fully how this principle appears in actual practice, a number of illustrations were given of its actual application to a variety of trades. These indicate the way the principle is applied and the results accruing. The relationship of co-partnership societies to trade-unions has always been of an amicable character, because co-partnership societies set out with the determination to pay at least the trade-union rate of wages and conform to the trade-union conditions of the district in which their workshops are established. In several instances they have set the pace in better wages, better conditions, and shorter hours of labour, some societies already working forty-eight hours per week, and others forty-nine and fifty hours per week, while the ordinary working hours are fifty-four. The good feeling existing is shown by several trade-unions investing their funds with co-partnership societies. That co-partnership principles commend themselves to captains of industry is proved by the application of the principle to several ordinary companies and firms. Representatives of these firms say the economic results have been good. This view is emphasised by the results of the South Metropolitan Gas Company. The approval of the co-partnership principle is shown by the opinion of the *Times* newspaper, of the *Review of Reviews*, and of Mr. Mosely, of American labour commission fame. The general conclusion arrived at was that the rightful aspirations of labour can only be met by this system of co-partnership; also that its acceptance would largely do away with the friction between capital and labour, while the result would be to widen the outlook of the workers, elevate their characters, give them a better business knowledge, and thus increase their efficiency.

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3. *The Co-operative Organisation of Consumers.* *By* T. Tweddell.

Co-operation is an appropriate theme for discussion in Leicester, a town of co-operative enterprise. It exhibits two phases in its development: (1) Co-operation organised in the interests of the worker as exemplified in the independent production workshops; (2) Co-operation organised in the interests of the consumer as exemplified in the 'store' and the 'wholesale.'

The stores originated in the 'hungry forties,' and were based upon the principle of 'profit upon cost,' the influence of which upon early co-operators was discussed. The Free Trade agitation naturally gave prominence to the interests of the consumer. The economic basis of the 'Rochdale Pioneers' was considered together with its important and far-reaching consequence, and the progress of the movement up to the present day was sketched. The constitution of the 'wholesales' was necessarily dictated by their parentage. These organisations have met with remarkable success and developed into widespread ramifications.

The causes which have contributed to the growth and progress of the consumers organisation are as follows:—

1. It represents the highest social interest, viz., that of the consumer.
2. It satisfies most completely the conditions imposed by modern industrial progress.
3. It provides the most effective system of thrift ever devised.
4. It is in harmony with modern social and economic tendencies.
5. It has in it the elements of unlimited expansion.

4. *Economic Theory and the Formation of Trusts.* *By* H. W. Macrosty, *B.A.*

The theorist describes as 'normal' combinations unions of representative firms to realise external economies of the market. The representative firm, however, is hardly discoverable, and combinations of representative firms are very few and weak, being exposed to the destructive competition of the weak firms outside.

The common form (described by theorists as 'abnormal') arises out of the inability of the private firm to foresee and control the market. The desire to make a living and readiness to fight for the chance to do so generate competition as a natural outlet of human activity. Hence naturally (or normally) proceeds excessive competition. Desire to control or suppress competition is the fundamental principle of all combinations, and therefore the common form is really 'normal.' This is important, since our view of what is 'normal' in the combination movement may colour our view of the future of that movement.

Tariffs exercise a direct influence in the direction of combination in Protectionist countries. The view that indirectly they promote the same tendency in other countries seems contradicted by the spread of combination in trades not affected by Protection. General free trade, even if it dissolved some unions, would by increasing competition produce internationally the same state out of which have arisen domestic combinations.

Over-capitalisation attends the origin of combination, but only because over-capitalisation is an essential condition of over-competition. Either by competition or by combination over-capitalisation must be eliminated, and combination does it in the most peaceful and gradual manner. This refers only to moderate over-capitalisation, and not to criminal or foolish valuations.

There is nothing in economics hostile to the view that the large amalgamation will be the dominant industrial form of the future; but this will depend on the man of business, and not on the man of theory.

5. *The Development of Trusts. By* D. H. MACGREGOR, *M.A.*

Many of the causes of Trusts are historical, and due to the progress of invention in machinery and transport. These must, in any case, have created a larger manufacturing unit.

Accidental causes have also operated, such as tariffs, forms of taxation, the influence of strong personalities, and of national sentiment. When these have given the 'momentum of the start,' Trusts maintain themselves by various forms of what is best called 'economic advantage.' This advantage has been allied to forms of competition which were not allowed for in orthodox economic theory.

It seems certain that we must reckon with Trusts in some form for the future. The difficult problem is between their ultimate nationalisation and their legislative control. The latter has not had a distinguished history. The former is beset with all the difficulties of socialism.

Section G.—ENGINEERING.

President of the Section.—Professor Silvanus P. Thompson, B.A., D.Sc., F.R.S.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

It would be impossible for any assembly of engineers to meet in annual gathering at the present time without some reference to the severe loss which the profession has so recently sustained by the death of Sir Benjamin Baker. Born in 1840, he had attained while still a comparatively young man to a position in the front rank of constructive engineers. His contributions to science cover a considerable range, but were chiefly concerned with the strength of materials, into which he made valuable investigations, and with engineering structures generally. His name will doubtless be chiefly associated with the building of great bridges, to the theory of which he contributed an important memoir entitled 'A Theoretical Investigation into the Most Advantageous System of Constructing Bridges of Great Span.' In this work he set forth the theory of the cantilever bridge. Upon the plan there laid down he built the Forth Bridge, besides many other large bridges in various parts of the world. With that memorable structure, completed in 1890, his name will ever be associated; but he will be remembered henceforth also as the engineer who was responsible for the great dam across the Nile at Assouan, a work which promises to have an influence for all time upon the fortunes of Egypt and upon the prosperity of its population. Sir Benjamin Baker was, moreover, closely associated with the internal railways of London, both in the early days of the Metropolitan Railway and in the later developments of the deep-level tubes. He was elected a Fellow of the Royal Society in 1890, became President of the Institution of Civil Engineers in 1895, and was a member of Council of the Institution of Mechanical Engineers, besides being an active member of the Royal Institution and of the British Association. He was also a member of the Council of the Royal Society at the time of his death.

He enjoyed many honorary distinctions, including degrees conferred by the Universities of Cambridge and Edinburgh. In 1890 there was conferred upon him the title of K.C.M.G., and in 1902 that of K.C.B.

He had but just returned from Egypt, whither he had gone in connection with the project for raising the height of the Assouan dam, so as to increase its storage to more than double the present volume, when he died very suddenly on May 19, in his sixty-seventh year.

The Development of Engineering and its Foundation on Science.

We live in an age when the development of the material resources of civilisation is progressing in a ratio without parallel. International commerce spreads apace. Ocean transport is demanding greater facilities. Steamships of vaster size and swifter speed than any heretofore in use are being built every year. Not

only are railways extending in all outlying parts of the world, but at home, where the territory is already everywhere intersected with lines, larger and heavier locomotives are being used, and longer runs without stopping are being made by our express trains. The horsed cars on our tramways are now being mostly superseded by larger cars, electrically propelled and travelling with greatly increased speeds. For the handling of the ever-increasing passenger traffic in our great cities electric propulsion has shown itself a necessity of the time; witness the electric railways in Liverpool and the network of electrically worked tube railways throughout London. In ten years the manufacture of automobile carriages of all sorts has sprung up into a great industry. Every year sees a greater demand for the raw materials and products, out of which the manufacturer will in turn produce the articles demanded by our complex modern life. We live and work in larger buildings; we make more use of mechanical appliances; we travel more, and our travelling is more expeditious than formerly; and not we alone, but all the progressive nations. The world uses more steel, more copper, more aluminium, more paper; therefore requires more coal, more petroleum, more timber, more ores, more machinery for the getting and working of them, more trains and steamships for their transport. It requires machines that will work faster or more cheaply than the old ones to meet the increasing demands of manufacture; new fabrics; new dyes; even new foods; new and more powerful means of illumination; new methods of speaking to the ends of the earth.

We must not delude ourselves with imagining that the happiness and welfare of mankind depend only on its material advancement; or that moral, intellectual, and spiritual forces are not in the ultimate resort of greater moment. But if the inquiry be propounded what it is that has made possible this amazing material progress, there is but one answer that can be given—science. Chemistry, physics, mechanics, mathematics, it is these that have given to man the possibility of organising this tremendous development. And the great profession which has been most potent in applying these branches of science to wield the energies of Nature and direct them to the service of man has been that of the engineer. Without the engineer how little of all this activity could there have been; and without mathematics, mechanics, physics, and chemistry, where were the engineer?

If looking over this England of Edward the Seventh we try to put ourselves back into the England of Edward the Sixth—or for that matter of any pre-Victorian monarch—we must admit that the differences to be found in the social and industrial conditions around us are due not in any appreciable degree to any changes in politics, philosophy, religion, or law, but to science and its applications. If we look abroad, and contrast the Germany of Wilhelm the Second with the Germany of Charles the Fifth, we shall come to the like conclusion. So also in Italy, in Switzerland, in every one indeed of the progressive nations. And it is precisely in the stagnant nations, such as Spain, or Servia, where the cultivation of science has scarcely begun, that the social conditions remain in the backward state of the Middle Ages.

Interaction of Abstract Science and its Applications.

In engineering, above all other branches of human effort, we are able to trace the close interaction between abstract science and its practical applications. Often as the connection between pure science and its applications has been emphasised in addresses upon engineering, the emphasis has almost always been laid upon the influence of the abstract upon the concrete. We are all familiar with the doctrine that the progress of science ought to be an end in itself, that scientific research ought to be pursued without regard to its immediate applications, that the importance of a discovery must not be measured by its apparent utility at the moment. We are assured that research in pure science is bound to work itself out in due time into technical applications of utility, and that the pioneer ought not to pause in his quest to work out potential industrial developments. We are invited to consider the example of the immortal Faraday, who

deliberately abstained from busying himself with marketable inventions arising out of his discoveries, excusing himself on the ground that he had no time to spare for money-making. It is equally true, and equally to the point, that Faraday, when he had established a new fact or a new physical relation, ceased from busying himself with it and pronounced that it was now ready to be handed over to the mathematicians. But, admitting all these commonplaces as to the value of abstract science in itself and for its own sake, admitting also the proposition that sooner or later the practical applications are bound to follow on upon the discovery, it yet remains true that in this thing the temperament of the discoverer counts for something. There are scientific investigators who cannot pursue their work if troubled by the question of ulterior applications; there are others no less truly scientific who simply cannot work without the definiteness of aim that is given by a practical problem awaiting solution. There are Willanses as well as Regnaults; there are Whitworths as well as Poissons. The world needs both types of investigator; and it needs, too, yet another type of pioneer—namely, the man who, making no claim to original discovery, by patient application and intelligent skill turns to industrial fruitfulness the results already attained in abstract discovery.

There is, however, another aspect of the relation between pure and applied science, the significance of which has not been hitherto so much emphasised, but yet is none the less real—the reaction upon science and upon scientific discovery of the industrial applications. For while pure science breeds useful inventions, it is none the less true that the industrial development of useful inventions fosters the progress of pure science. No one who is conversant with the history, for example, of optics can doubt that the invention of the telescope and the desire to perfect it were the principal factors in the outburst of optical science which we associate with the names of Newton, Huygens, and Euler. The practical application, which we know was in the minds of each of these men, must surely have been the impelling motive that caused them to concentrate on abstract optics their great and exceptional powers of thought. It was in the quest—the hopeless quest—of the philosopher's stone and the elixir of life that the foundations of the science of chemistry were laid. The invention of the art of photography has given immense assistance to sciences as widely apart as meteorology, ethnology, astronomy, zoology, and spectroscopy. Of the laws of heat men were profoundly ignorant until the invention of the steam engine compelled scientific investigation; and the new science of thermodynamics was born. Had there been no industrial development of the steam engine, is it at all likely that the world would ever have been enriched with the scientific researches of Rankine, Joule, Regnault, Hirn, or James Thomson? The magnet had been known for centuries, yet the study of it was utterly neglected until the application of it in the mariners' compass gave the incentive for research.

The history of electric telegraphy furnishes a very striking example of this reflex influence of industrial applications. The discovery of the electric current by Volta and the investigation of its properties appear to have been stimulated by the medical properties attributed in the preceding fifty years to electric discharges. But, once the current had been discovered, a new incentive arose in the dim possibility it suggested of transmitting signals to a distance. This was certainly a possibility, even when only the chemical effects of the current had yet been found out. Not, however, until the magnetic effects of the current had been discovered and investigated did telegraphy assume commercial shape at the hands of Cooke and Wheatstone in England and of Morse and Vail in America. Let us admit freely that these men were inventors rather than discoverers: exploiters of research rather than pioneers. They built upon the foundations laid by Volta, Oersted, Sturgeon, Henry, and a host of less famous workers. But no sooner had the telegraph become of industrial importance, with telegraph lines erected on land and submarine cables laid in the sea, than fresh investigations were found necessary; new and delicate instruments must be devised; means of accurate measurement heretofore undreamed of must be found; standards for the comparison of electrical quantities must be created,

and the laws governing the operations of electrical systems and apparatus must be investigated and formulated in appropriate mathematical expressions. And so, perforce, as the inevitable consequence of the growth of the telegraph industry, and mainly at the hands of those interested in submarine telegraphy, there came about the system of electrical and electromagnetic units, based on the early magnetic work of Gauss and Weber, developed further by Lord Kelvin, by Bright and Clark, and last but not least by Clerk Maxwell. Had there been no telegraph industry to force electrical measurement and electrical theory to the front, where would Clerk Maxwell's work have been? He would probably have given his unique powers to the study of optics or geometry; his electromagnetic theory of light would never have leapt into his brain; he would never have propounded the existence of electric waves in the ether. And then we should never have had the far-reaching investigations of Heinrich Hertz; nor would the British Association at Oxford in 1894 have witnessed the demonstration of wireless telegraphy by Sir Oliver Lodge. A remark of Lord Rayleigh's may here be recalled, that the invention of the telephone had probably done more than anything else to make electricians understand the principle of self-induction.

In considering this reflex influence of the industrial applications upon the progress of pure science it is of some significance to note that for the most part this influence is entirely helpful. There may be sporadic cases where industrial conditions tend temporarily to check progress by imposing persistence of a particular type of machine or appliance; but the general trend is always to help to new developments. The reaction aids the action; the law that is true enough in inorganic conservative systems, that reaction opposes the action, ceases here to be applicable, as indeed it ceases to be applicable in a vast number of organic phenomena. It is the very instability thereby introduced which is the essential of progress. The growing organism acts on its environment, and the change in the environment reacts on the organism—not in such a way as to oppose the growth, but so as to promote it. So is it with the development of pure science and its practical applications.

In further illustration of this principle one might refer to the immense effect which the engineering use of steel has had upon the study of the chemistry of the alloys. And the study of the alloys has in turn led to the recent development of metallography. It would even seem that through the study of the intimate structure of metals, prompted by the needs of engineers, we are within measurable distance of arriving at a knowledge of the secret of crystallogenesis. Everything points to the probability of a very great and rapid advance in that fascinating branch of pure science at no distant date.

History of the Development of Electric Motive Power.

There is, however, one last example of the interaction of science and industry which may claim closer attention. In the history of the development of the electric motor one finds abundant illustration of both aspects of that interaction.

We go back to the year 1821, when Faraday, after studying the phenomena of electromagnetic deflexion of a needle by an electric current (Oersted's discovery), first succeeded in producing continuous rotations by electromagnetic means. In his simple apparatus a piece of suspended copper wire, carrying a current from a small battery, and dipping at its lower end into a cup of mercury, rotated continuously around the pole of a short bar-magnet of steel placed upright in the cup. In another variety of this experiment the magnet rotated around the central wire, which was fixed. These pieces of apparatus were the merest toys, incapable of doing any useful work; nevertheless they demonstrated the essential principle, and suggested further possibilities. Two years later, Barlow, using a star-wheel of copper, pivoted so that the lowest point of the star should make contact with a small pool of mercury, found that the star-wheel rotated if a current was sent through the arm of the star while the arm itself was situated between the poles of a steel horseshoe-magnet. Shortly afterwards Sturgeon improved the apparatus by substituting a copper disc for the star-wheel. The action was the same.

A conductor, carrying an electric current, if placed in a magnetic field, is found to experience a mechanical drag, which is neither an attraction nor a repulsion, but a lateral force tending to move it at right angles to the direction of flow of the current and at right angles to the direction of the lines of the magnetic field in which it is situated. Still this was a toy. Two years later came the announcement by Sturgeon of the invention of the soft-iron electromagnet, one of the most momentous of all inventions, since upon it practically the whole of the constructive part of electrical engineering is based. For the first time mankind was furnished with a magnet the attractive power of which could be increased absolutely indefinitely by the mere expenditure of sufficient capital upon the iron core and its surrounding copper coils, and the provision of a sufficiently powerful source of electric current to excite the magnetisation. Furthermore the magnet was under control, and could be made to attract or to cease to attract at will by merely switching the current on or off; and, lastly, this could be accomplished from a distance, even from great distances away. How slowly the importance of this discovery was recognised is now a matter for astonishment. To state that Sturgeon died in poverty twenty-six years later is sufficient to indicate his place among the unrequited pioneers of whom the world is not worthy. Six years elapsed, and then there came a flood of suggestions of electric motors in which was applied the principle of intermittent attraction by an electromagnet. Henry in 1831 and Dal Negro in 1832 produced see-saw mechanisms so operated. Ritchie in 1833 and Jacobi in 1834 devised rotatory motors. Ritchie pivoted a rapidly commutated electromagnet between the poles of a permanent magnet—a true type of the modern motor—while Jacobi caused two multipolar electromagnets, one fixed, one movable, to put a shaft into rotation and propel a boat. A perplexing diminution of the current of the battery whenever the motor was running caused Jacobi to investigate mathematically the theory of its action. In a masterly memoir he laid down a few years later the theory of electric motive power. But in the intervening period, in 1831, Faraday had made the cardinal discovery of the mechanical generation of electric currents by magneto-electric induction, the fundamental principle of the dynamo. Down to that date the only known way —save for the feeble currents of thermopiles—to generate electric currents had been the pile of Volta, or one of the forms of battery which had been evolved from it. Now, by Faraday's discovery, the world had become possessed of a new source. And yet again, strange as it may seem, years elapsed before the world—that is, the world of engineers—discovered that an important discovery had been made. Not till some thirty years later were any magneto-electric machines made of a sufficient size to be of practical service even in telegraphy, and none were built of a sufficient power to furnish a single electric light until about the year 1857. In the meantime in America other electric motors, to be driven by batteries, had been devised by Devonport and by Page; the latter's machine had an iron plunger to be sucked by electromagnetic attraction into a hollow coil of copper wire, thereby driving a shaft and flywheel through the intermediate action of a connecting-rod and crank. Page's was, in fact, an electric engine, with 2-foot stroke, single-acting, of between 3 and 4 horse-power. The battery occupied about 3 cubic feet and consumed, according to Page, 3 lb. of zinc per horse-power per day. This must have been an under-estimate; for if Daniell's cells were used the minimum consumption for a motor of 100 per cent. efficiency is known to be about 2 lb. of zinc per horse-power per hour.

Electric Motive Power Impossible in 1857.

Upon the state of development of electric motors fifty years ago information may be gleaned from an exceedingly interesting debate at the Institution of Civil Engineers upon a paper read April 21, 1857, 'On Electromagnetism as a Motive Power,' by Mr. Robert Hunt, F.R.S. In this paper the author states that, though long-enduring thought has been brought to bear upon the subject, and large sums of money have been expended on the construction of machines, 'yet there does not appear to be any nearer approach to a satisfactory result than there was

thirty years ago.' After explaining the elementary principles of electromagnetism, he describes the early motors of Dal Negro, Jacobi, Davenport, Davidson, Page, and others. Reviewing these and their non-success as commercial machines, he says: 'Notwithstanding these numerous trials . . . it does not appear that any satisfactory explanation has ever been given of the causes which have led to the abandonment of the idea of employing electricity as a motive power. It is mainly with the view of directing attention to these causes that the present communication has been written.' He admits that electromagnets may be constructed to give any desired lifting power; but he finds that the attractive force on the iron keeper of a magnet of his own, which held 220 lb. when in contact, fell to 36 lb. when the distance apart was only one-fiftieth of an inch. To this rapid falling off of force, and to the hardening action on the iron of the repeated vibrations due to the mechanical concussion of the keeper, he attributed the small power of the apparatus. Also he remarked upon the diminution of the current which is observed to flow from the battery when the motor was running (which Jacobi had, in his memoir on the theory, traced to a counter electromotive force generated in the motor itself), and which reduced the effort exerted by the electromagnets; this diminution he regarded as impairing the efficiency of the machine. 'All electromagnetic arrangements,' he says, 'suffer from the cause named, a reduction of the mechanical value of the prime mover, in a manner which has no resemblance to any of the effects due to heat regarded as a motive power.' Proceeding to discuss the batteries he remarked that as animal power depends on food, and steam power on coal, so electric power depends on the amount of zinc consumed; in support of which proposition he cited the experiments of Joule. He gives as his own results that for every grain of zinc consumed in the battery his motor performed a duty equivalent to lifting 86 lb. one foot high. Joule and Scoresby, using Daniell's cells, had found the duty to be equivalent to raising 80 lb. one foot high, being about half the theoretical maximum duty for one grain of zinc. In the Cornish engine, doing its best duty, one grain of coal was equivalent to a duty of raising 143 lb. one foot high. He put the price of zinc at 35*l.* per ton as compared with coal at less than 1*l.* per ton, which makes the cost of power produced by an electric motor—if computed by the consumption of zinc in a battery—about sixty times as great as that of an equal power produced by a steam-engine consuming coal. He concludes that 'it would be far more economical to burn zinc under a boiler and to use it for generating steam power than to consume zinc in a battery for generating electromagnetical power.'

In the discussion which followed, several men of distinction took part. Professor William Thomson, of Glasgow (Lord Kelvin), wrote, referring to the results of Joule and Scoresby: 'These facts were of the highest importance in estimating the applicability of electromagnetism, as a motive power, in practice; and, indeed, the researches alluded to rendered the theory of the duty of electromagnetic engines as complete as that of the duty of waterwheels was generally admitted to be. Among other conclusions which might be drawn from these experiments was this: that, until some mode of producing electricity as many times cheaper than that of an ordinary galvanic battery as coal was cheaper than zinc, electromagnetic engines could not supersede the steam-engine.' Mr. W. R. Grove (Lord Justice Sir William Grove) remarked that a practical application of the science appeared to be still distant. The great desideratum, in his opinion, was not so much improvement in the machine as in the prime mover, the battery, which was the source of power. At present the only available use for this power must be confined to special purposes where the danger of steam and the creation of vapour were sought to be avoided, or where economy of space was a great consideration. Professor Tyndall agreed with the last speaker, but suggested that there might be some way of mitigating the apparent diminution of power due to the induction of opposing electromotive forces in the machine itself. Mr. C. Cowper spoke of some experiments, made by himself and Mr. E. A. Cowper, showing the advantage gained by properly laminating the iron cores used in the motor. He put the cost of electric power at 4*l.* per horse-power per

hour. He deprecated building electric motors with reciprocating movements and cranks; described the use of silver commutators; and mentioned the need of adjusting the lead given to the contacts. There was, he said, no reason to suppose that electric motors could be made as light as steam-engines. Even in the case of small motors of one-tenth or one-hundredth of a horse-power, for light work, where the cost of power was of small consequence, a boy or a man turning a winch would probably furnish power at a cheaper rate. Mr. Alfred Smee agreed that the cost would be enormous for heavy work. Although motive power could not at present be produced at the same expense on a large scale by the battery as by coal, still they were enabled readily to apply the power at any distance from its source; the telegraph might be regarded as an application of motive power transmitted by electricity. Mr. G. P. Bidder considered that there had been a lamentable waste of ingenuity in attempting to bring electromagnetism into use on a large scale. Mr. Joule wrote to say that it was to be regretted that in France the delusion as to the possibility of electromagnetic engines superseding steam still prevailed. He pointed out, as a result of his calorimeter experiments, that if it were possible so to make the electric engine work as to reduce the amount to a small fraction of the strength which it had when the engine was standing still, nearly the whole of the heat (energy) due to the chemical action of the battery might be evolved as work. The less the heat evolved, as heat, in the battery, the more perfect the economy of the engine. It was the lower intensity of chemical action of zinc as compared with carbon, and the relative cost of zinc and coal, which decided so completely in favour of the steam-engine. Mr. Hunt, replying to the speakers in the discussion, said that his endeavour had been to show that the impossibility of employing electromagnetism as a motive power lay with the present voltaic battery. Before a steam-engine could be considered, the boiler and furnace must be considered. So likewise must the battery if electric power were to become economical. Then the President, Mr. Robert Stephenson, wound up the discussion by remarking that there could be no doubt that the application of voltaic electricity, in whatever shape it might be developed, was entirely out of the question, commercially speaking. The mechanical application seemed to involve almost insuperable difficulties. The force exhibited by electromagnetism, though very great, extended through so small a space as to be practically useless. A powerful magnet might be compared to a steam-engine with an enormous piston, but with exceedingly short stroke; an arrangement well known to be very undesirable.

In short, the most eminent engineers in 1857 one and all condemned the idea of electric motive power as unpractical and commercially impossible. Even Faraday, in his lecture on 'Mental Education' in 1854, had set down the magneto-electric engine along with mesmerism, homœopathy, odylism, the caloric engine, the electric light, the sympathetic compass, and perpetual motion as coming in different degrees amongst 'subjects uniting more or less of the most sure and valuable investigations of science with the most imaginary and unprofitable speculation, that are continually passing through their various phases of intellectual, experimental, or commercial development, some to be established, some to disappear, and some to recur again and again, like ill weeds that cannot be extirpated, yet can be cultivated to no result as wholesome food for the mind.'

Fifty years later.

Fifty years have fled, and Hunt, Grove, Smee, Tyndall, Cowper, Joule, Bidder, and Stephenson have long passed away. Lord Kelvin remains the sole and honoured survivor of that remarkable symposium. But the electric motor is a *gigantic practical success*, and the electric motor industry has become a very large one, employing thousands of hands. Hundreds of factories have discarded their steam-engines to adopt electric-motor driving. All travelling cranes, nearly all tramcars, are driven by electric motors. In the Navy and in much of the merchant service the donkey-engines have been replaced by electric motors. Electric motors of all sizes and outputs, from one-twentieth of a horse-

power to 8,000 horse-power, are in commercial use. One may well ask: What has wrought this astonishing revolution in the face of the unanimous verdict of the engineers of 1857?

The answer may be given in terms of the action and reaction of pure and applied science. Pure science furnished a discovery; industrial applications forced its development; that development demanded further abstract investigation, which in turn brought about new applications. It was beyond all question the development of the dynamo for the purposes of electrotyping and electric light which brought about the commercial advent of the electric motor. For about that very time Holmes and Siemens and Wilde and Wheatstone were at work developing Faraday's magneto-electric apparatus into an apparatus of more practical shape; and the electric lighthouse lamp was becoming a reality which Faraday lived to see before his death in 1867. That eventful year witnessed the introduction of the more powerful type of generator which excited its own magnets. And even before that date a young Italian had made a pronouncement which, though it was lost sight of for a time, was none the less of importance. Antonio Pacinotti in 1864 described a machine of his own devising, having a specially wound revolving ring-magnet placed between the poles of a stationary magnet, which, while it would serve as an admirable generator of electric currents if mechanically driven, would also serve as an excellent electric motor if supplied with electric currents from a battery. He thereupon laid down the principle of reversibility of action, a principle more or less dimly foreseen by others, but never before so clearly enunciated as by him. And so it turned out in the years from 1860 to 1880, when the commercial dynamo was being perfected by Gramme, Wilde, Siemens, Crompton, and others, that the machines designed specially to be good and economical generators of currents proved themselves to be far better and more efficient motors than any of the earlier machines which had been devised specially to work as electro-magnetic engines. Moreover, with the perfection of the dynamo came that cheap source of electric currents which was destined to supersede the battery. That a dynamo driven by a steam engine furnishing currents on a large scale should be a more economical source of current than a battery in which zinc was consumed, does not appear to have ever occurred to the engineers who, in 1857, discussed the feasibility of electric motive power. Indeed, had any of them thought of it, they would have condemned the suggestion as chimerical. There was a notion abroad—and it persisted into the eighties—that no electric motor could possibly have an efficiency higher than 50 per cent. This notion, based on an erroneous understanding of the theoretical investigations of Jacobi, certainly delayed the progress of events. Yet the clearest heads of the time understood the matter more truly. The true law of efficiency was succinctly stated by Lord Kelvin in 1851, and was recognised by Joule in a paper written about the same date. In 1877 Mascart pointed out how the efficiency of a given magneto-electric machine rises with its speed up to a limiting value. In 1879 Lord Kelvin and Sir William Siemens gave evidence before a Parliamentary Committee as to the possible high efficiency of an electric transmission of power; and in August of the same year, at the British Association meeting at Sheffield, the essential theory of the efficiency of electric motors was well and admirably put in a lecture by Professor Ayrton. In 1882 the present author designed, in illustration of the theory, a graphic construction, which has been ever since in general use to make the principle plain. The counter-electromotive force generated by the motor when running, which Hunt and Tyndall deplored as a defect, is the very thing which enables the motor to appropriate and convert the energy of the battery. Its amount relatively to the battery's own electromotive force is the measure of the degree to which the energy which would otherwise be wasted as heat is utilised as power. Pure science stepped in, then, to confirm the possibility of a high efficiency in the electric motor *per se*. But pure science was also brought into service in another way. An old and erroneous notion, which even now is not quite dead, was abroad to the effect that the best way of arranging a battery was so to group its component cells that its internal resistance

should be equal to the resistance of the rest of the circuit. If this were true, then no battery could ever have an efficiency of more than 50 per cent. It was supposed in many quarters that this misleading rule was applicable also to the dynamo. The dynamo makers discovered for themselves the fallacy of this idea, and strove to reduce the internal resistance of the armatures of their machines to a minimum. Then the genius of the lamented John Hopkinson led him to apply to the design of the magnetic structure of the dynamo abstract principles upon which a rational proportioning of the iron and copper could result. A similar investigation was independently made by Gisbert Kapp, and between these accomplished engineers the foundations of dynamo design were set upon a scientific basis. To the perfection of the design the magnetic studies of our ex-President, Professor Ewing, contributed a notable part, since they furnished a basis for calculating out the inevitable losses of energy in armature cores by hysteresis and parasitic currents in the iron when subjected to recurring cycles of magnetisation. Able constructive engineers, Brown, Mordey, Crompton, and Kapp, perfected the structural development, and the dynamo within four or five years became, within its class, a far more highly efficient machine than any steam engine. And as by the principle of reversibility every dynamo is also capable of acting as a motor, the perfection of the dynamo implied the perfection, both scientific and commercial, of the motor also. The solution in the eighties of the problem how to make a dynamo to deliver current at a constant voltage when driven at a constant speed, found its counterpart in the solution by Ayrton and Perry of the corresponding problem how to make a motor which would run at constant speed when supplied with current at a constant voltage. Both solutions dep nd upon the adoption of a suitable compound winding of the field magnets.

A little later alternating currents claimed the attention of engineers; and the alternating current generator, or 'alternator,' was developed to a high degree of perfection. To perfect a motor for alternating currents was not so simple a matter. But again pure science stepped in, in the suggestion by Galileo Ferraris of the extremely beautiful theorem of the rotatory magnetic field, due to the combination of two alternating magnetic fields equal in amplitude, identical in frequency and in quadrature in space, but differing from each other by a quarter-period in phase. To develop on this principle a commercial motor required the ingenuity of Tesla and the engineering skill of Dobrowolsky and of Brown: and so the three-phase induction motor, that triumph of applied science, came to perfection. Ever since 1891, when at the Frankfort Exhibition there was shown the *tour de force* of transmitting 100 horse-power to a distance of 100 miles with an inclusive efficiency of 73 per cent., the commercial possibility of the electric transmission of power on a large scale was assured. The modern developments of this branch of engineering and the erection of great power-stations for the economic distribution of electric power generated by large steam plant or by water-turbines are known to all engineers. The history of the electric motor is probably without parallel in the lessons it affords of the commercial and industrial importance of science.

But the query naturally rises: If a steam-engine is still needed to drive the generator that furnishes the electric current to drive the motors, where does the economy come in? Why not use small steam-engines, and get rid of all intervening electric appliances? The answer, as every engineer knows, lies in the much higher efficiency of large steam-engines than of small ones. A single steam-engine of 1,000 horse-power will use many times less steam and coal than a thousand little steam-engines of 1 horse-power each, particularly if each little steam-engine required its own little boiler. The little electric motor may be designed, on the other hand, to have almost as high an efficiency as the large motor. And while the loss of energy due to condensation in long steam-pipes is most serious, the loss of energy due to transmission of electric current in mains of equal length is practically negligible. This is the abundant justification of the electric distribution of power from single generating centres to numerous electric motors placed in the positions where they are wanted to work.

Education and Training of Engineers.

Interplay of action and reaction make for progress not only in the evolution of the scientific industries, but also in the development of the individual engineer. In him, if his training is on right lines, pure theory becomes an aid to sound practice; and practical applications are continually calling him to resort to those abstractions of thought, the underlying principles, which when known and formulated are called theories. Recent years have brought about a so much better understanding of education, in its bearing upon the professions and constructive industries, that we now seldom hear the practical man denouncing theory, or the theorist pooh-poohing practice. It is recognised that each is useful, and that the best uses of both are in conjunction, not in isolation. As a result of this better understanding distinct progress is being made in the training of engineers. Of this the growth of the engineering departments of the universities, and of the technical colleges and schools, affords striking evidence. The technical schools, moreover, are recognising that their students must have a sound preliminary education, and are advancing in the requirements they expect of candidates for admission. They are also finding out how their work may best supplement the practical training in the shops, and are improving their curricula accordingly. In the engineering industry, too, Great Britain is slowly following the lead taken in America, Germany, and Switzerland, in the recognition afforded to the value of a systematic college training for the young engineer, though there is still much apathy and even distrust shown in certain quarters. Yet there is no doubt that the stress of competition, particularly of competition against the industry and the enterprise of the trained men of other nations, is gradually forcing to the front the sentiment in favour of a rational and scientific training for the manufacturer and for the engineer. As William Watson, in his 'Ode on the Coronation,' wrote in a yet wider sense of England:—

> For now the day is unto them that know,
> And not henceforth she stumbles on the prize;
> And yonder march the nations full of eyes.
> Already is doom a-spinning. . . .

Truly the day is 'unto them that know.' Knowledge, perfected by study and training, must be infused into the experience gained by practice: else we compete at very unequal odds with the systematically trained workers of other nations. Nor must we make the mistake here in the organisation of our technical institutions of divorcing the theory from its useful applications. In no department is this more vital than in the teaching of mathematics to engineering students. For while no sane person would deny that the study of mathematics, for the sole sake of mathematics, even though it leads to nothing but abstract mathematics, is a high and ennobling pursuit, yet that is not the object of mathematical studies in an engineering school. The young engineer must learn mathematics not as an end in itself, but as a tool that is to be useful to him. And if it is afterwards to be of use to him, he must learn it by using it. Hence the teacher of mathematics in an engineering school ought himself to be an engineer. However clever he be as a mathematical person, his teaching is unreal if he is not incessantly showing his learners how to apply it to the problems that arise in practice; and this he is incapable of doing if these problems do not lie within his own range of experience and knowledge. Were he a heaven-born senior wrangler, he is the wrong man to teach mathematics if he either despises or is ignorant of the ways in which mathematics enter into engineering. The fact is that for the great majority of engineering students, the mental training they most need is that which will enable them to think in physics, in mechanics, in geometric space, not in abstract symbols. The abstract symbols, and the processes of dealing with their relations and combinations, are truly necessary to them: but they are wanted not for themselves, but to form

convenient modes of expressing the physical facts and laws, and the interdependence of those physical facts and laws. When the student loses grip of the physical meaning of his equations, and regards them only as abstractions or groupings of symbols, woe betide him. His mathematics amount to a mere symbol-juggling. That is how paper engineers are made. The high and dry mathematical master who thinks it beneath him to show a student how to plot the equations $y = A \sin x$, or $r = b \sin \theta$, or who never culls an example or sets a problem from thermodynamics or electricity, must be left severely on one side as a fossil. Better a living Whitworth scholar than a dry-as-dust Cambridge wrangler. He at least knows that elasticity is something more real than the group of symbols $E = p \div \frac{\Delta x}{x}$, which any mathematician may 'know,' even though he be blissfully ignorant whether the force required to elongate a square-inch bar of steel by one one-millionth of its length is ten ounces or ten tons.

One evidence of the wholesome change of opinion that is springing up concerning the training of engineers is the abandonment of the system of taking premium pupils into works with no other test or qualification than that of the money-bag. Already many leading firms of engineers have been finding that the practice of taking sons of wealthy parents for a premium does not answer well, and is neither to their own advantage nor in many cases to that of the 'pupil,' whom it is nobody's particular business in the shops to train. Premium pupilage is absolutely unknown in the engineering firms of the United States or on the Continent of Europe. The firms who have abandoned it are finding themselves better served by taking the ablest young men from the technical schools and paying them small wages from the first, while they gain experience and prove themselves capable of good service. Messrs. Yarrow & Co. have led the way with a plan of their own, having three grades of apprenticeship, admission to which depends upon the educational abilities of the youths themselves. Messrs. Siemens have adopted a plan of requiring a high preliminary training. The Daimler Motor Company has likewise renounced all premiums, preferring to select young men of the highest intelligence and merit. Messrs. Clayton and Shuttleworth have quite recently reconstructed their system of pupil-apprenticeship on similar lines. The British Westinghouse Company and the British Thomson-Houston Company have each followed an excellent scheme for the admission of capable young men. Even the conservatism of the railway engineers shows signs of giving way; for already the Great Eastern Railway has modernised its regulations for the admission of apprentices. What the engineering staffs of the railway companies have lost by taking in pupils because of their fathers' purses rather than for the sake of their own brains it is impossible to gauge. But the community loses too, and has a right to expect reform.

To this question, affecting the whole future outlook of engineering generally, a most important contribution was made in 1906 by the publication by the Institution of Civil Engineers of the report of a committee (appointed in November 1903) to consider and report to the Council upon the subject of the best methods of education and training for all classes of engineers. This Committee, a most influential and representative body consisting of leading men appointed by the several professional societies, the Institutions of Civil, Mechanical, and Electrical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, the Institution of Gas Engineers, the Institution of Mining Engineers, and two northern societies, was ably and sympathetically presided over by Sir William H. White. Its inquiries lasted over two years and included the following sections: (1) Preparatory Training in Secondary Schools; (2) Training in Offices, Workshops, Factories, or on Works; (3) Training in Universities and Higher Technical Institutions; (4) Postgraduate Work. The findings of this Committee must be received as the most authoritative judgment of the most competent judges. So far as they relate to preparatory education they suggest a modernised secondary school curriculum in which there is no one specialised scientific study, but with emphasis on what may be called

sensible mathematics. They also formulated one recommendation so vital that it must be quoted in full :—

'A leaving examination for secondary schools, similar in character to those already existing in Scotland and Wales, is desirable throughout the United Kingdom. It is desirable to have a standard such that it could be accepted by the Institution [of Civil Engineers] as equivalent to the Studentship Examination, and by the Universities and Colleges as equivalent to a Matriculation Examination.'

One may well wonder why such a reasonable recommendation has not long ago been carried out by the Board of Education. Perhaps it has been too busy over the religious squabble to attend to the pressing needs of the nation.

The second set of recommendations relates to engineering training. It begins with the announcement that 'long experience has led to general agreement among engineers as to the general lines on which practical training should proceed'; but goes into no recommendations on this head beyond favouring four years in workshops, on works, in mines, or in offices, expressing the pious desire that part of this practical training should be obtained in drawing-offices, and suggesting that during workshop-training the boys should keep regular hours, be subject to discipline, and be paid wages. It then lays down a dozen recommendations as to the 'academic' training suitable for the average boy. He should leave school about seventeen; he should have a preliminary year, or introductory workshop course of a year, either between leaving school and entering college, or after the first year of college training. If the workshop course follows straight on leaving school there must be maintenance of studies either by private tuition or in evening clases, so that systematic study be not suspended. For the average student, if well prepared before entering college, the course should last three academic years (three sessions); in some cases this might be extended to four or shortened to two. A sound and extensive knowledge of mathematics is necessary in all branches of engineering, and those departments of mathematics which have no bearing upon engineering should not claim unnecessary time or attention. The Committee strongly recommends efficient instruction in engineering drawing. The college course should include instruction (necessarily given in the laboratory) in testing materials and structures, and in the principles underlying metallurgical processes. In the granting of degrees, diplomas, and certificates, importance should be attached to laboratory and experimental work performed by individual students, and such awards should not depend on the results of terminal or final examinations alone.

All this is most excellent. It will be seen that it is entirely incompatible with the premium-pupil system, which may therefore be regarded as having been weighed and found wanting. For two things clearly stand out; that the young engineer must be college-trained, and that when he goes to works he should be regularly paid. It would have been well if the Committee could have been more explicit as to the proper course of workshop training; for instance as to the systematic drafting of the young engineer through the shops—forge, foundry, pattern-shop, fitting-shop, &c., and as to the proper recognition of the duty of the shop-foreman to allocate work to the novice in suitable routine. These are doubtless among the matters in which 'long experience has led engineers to general agreement.' But this being so, it would have been well to state them authoritatively. A notable feature of this report is its healthy appreciation of the advantages of training, and an equally healthy distrust of the practice of cramming for examinations. So soon as any subject is crammed, it ceases to afford a real training. 'Nature provides a very convenient safety-valve for knowledge too rapidly acquired.' It is even whispered that a new species of crammer has arisen to 'prepare' candidates in engineering for the graduate examinations of the Institution of Civil Engineers. The distinguished framers of this epoch-making report on the education and training of engineers at least give no countenance to any such parasitical development. For the scheme of education and training at which the Committee has aimed is genuinely scientific, a happy federation of the theoretical with the practical. It seeks to place the

training on a broad basis, and to secure to every future engineer worthy of the name the advantage of learning his professional work in both its aspects. It seeks, in short, to take advantage of that reflex action between science and its applications in which lies the greatest stimulus to progress. Its adoption will utilise for the young engineer, and therefore for the engineering industry as a whole, the facilities for training now so widely afforded throughout the country. If the institutions, schools, and colleges where engineering training is offered are but rightly developed and co-ordinated, the engineers of Great Britain need have no fear as to holding their own against the trained engineers of other countries It is for the employers to make use of these institutions, and to show that sympathetic interest in their efficiency which is essential to their full success.

The following Paper was then read:—

The Present Condition of Gas and Petrol Engines.[1]
By DUGALD CLERK, *M.Inst.C.E.*

FRIDAY, AUGUST 2.

The following Paper was read:—

On the Gases exhausted from a Petrol Motor.[2]
By B. HOPKINSON, *M.A.*

Joint Discussion with Section B on Explosion Temperatures.[3]

MONDAY, AUGUST 5.

The following Papers were read:—

1. *Pupin's Compensated Cable for Telephone Transmission.*[4]
By Sir W. H. PREECE, *K.C.B., F.R.S.*

2. *Tuning in Wireless Telegraphy. By* Sir OLIVER LODGE, *F.R.S.*

The principles of tuning were clearly explained by Mr. Duddell in his evening lecture to the Association last Friday, and I shall assume them known; but it is not to be supposed that the application of these principles requires the arc. Sufficient tuning for all practical purposes can be obtained by using the right kind of spark. It is possible to require too long a train of waves, in which case the latter half of the train will undo what the former half has begun, in analogy with beats. Thirty or forty swings can be easily got by a spark, and that is enough for practical requirements.

Effect of the Earth.

But attention to the spark alone is not sufficient; it is necessary to eliminate the influence of the earth.

For the snappy or non-tuned emission, such as was employed by Mr. Marconi for great distances, it is convenient to use an elevated wire on the one hand, and the earth on the other; but for a tuned station this is not appropriate.

[1] Published in *Electrician*, August 9.
[2] Published in *Engineering*, August 9.
[3] Reported in *Engineering*, August 9.
[4] Published in *Electrician*, August 9.

A tuned station requires two capacity areas, both elevated above the earth, as published by me in 1897. These capacity areas are usually horizontal frames, of shapes devised by my friend and partner, Dr. Alexander Muirhead, who has found that there is a best position for the lower aërial, such that the capacity is a minimum. The sending efficiency is then most marked.

If the lower aërial be too much raised, the radiating power diminishes; if it be lowered, the train of waves is shortened until, when it is allowed to touch the earth—*still* more if it is connected with the earth—there is hardly any train of waves at all, and the discharge is almost dead-beat. There is a great advantage in thus getting rid of earth contacts, inasmuch as variations of moisture and uncertainties of the soil do not enter in to confuse the problem and throw the tuning out. But even if the earth remained constant it would be deleterious: it seems by its resistance to damp out the vibrations and shortens the train of waves, in so far as it is allowed to exert any influence.

Kind of Spark.

A non-tuned station puts all the energy into a single snap, so as to produce a single discontinuous pulse calculated to affect every kind of station within the range of its power. For a tuned station this sudden snappy spark is to be avoided. The ideal arrangement is a spark of a sufficient number of alternations, of approximately equal strength, no one of which is sufficient to operate, but such that the accumulated influence of all of them is powerful. Instead therefore of the clean polished metal knobs in fresh or compressed air, which are suitable for a snappy spark, a tuned station may employ a series of points enclosed in ionised air so as to maintain conduction as long as possible. The maintenance is also assisted by using an alternator with a curve of the right shape—not a sine curve, but a high-shouldered curve—so as to keep up the stimulating potential for a sufficient time. It is this kind of spark which, at the Lodge-Muirhead station at Elmers End, was photographed by Mr. Duddell in a revolving mirror, and was exhibited by him on Friday night.

Method of Receiving from a Distant Tuned Station.

The first thing is to tune up the receiver accurately. This can be done by a Duddell radio-micrometer, which measures the received energy satisfactorily although it is very small. Tuning is altered until the reading on this micrometer rises to a high value; then the receiving apparatus is purposely made insensitive, so that the coherer will only respond to this high value: in other words, to the top of the curve. The message can then be received from the desired station. If the receiving apparatus were left sensitive, it would be affected violently by the desired station, but it would pick up a number of disturbances from other stations. By working at the top of the curve it feels the desired station alone.

Perfection of Tuning.

In this way it was possible to receive at Hythe from Elmers End while a much more powerful and nearer station at Dover was making a disturbance which was entirely eliminated. It is easy to hear the ships in the Channel, but it is also easy to tune everything out and listen to the desired station alone. A 5 per cent. change could be made to throw this out and throw a neighbouring one in; but in practice it would be undesirable to try to work quite so close as that.

With changes of that order of magnitude, however, several neighbouring sending stations can be made to send to several neighbouring receiving stations without interference. That is to say, diplex telegraphy is possible, though not duplex.

Tuning at the Sending End.

In order to economise power, it is desirable to have every part tuned. The aërials connected through the secondary of a peculiarly made Ruhmkorff coil

constitute one oscillating system of a low frequency, to correspond to an ordinary commercial alternator which excites them. When the swing is worked up they burst through the spark gap, short-circuiting out the Ruhmkorff and giving excessively rapid oscillations, which are the ones transmitted. These are picked up by the receiving station and are transferred at constant frequency into a closed air-condenser circuit, which, when its swings reach a maximum, overflows into the coherer. This is called the 'overflow method,' and was described by me in 1889 and 1891.

Ratio of Received to Emitted Energy.

Theoretical calculation shows that the energy received, compared with energy radiated, depends on the cube of the linear dimensions of emitter and receiver, if they are alike, and likewise on the cube of the distance between them.

Measurements made with the radio-micrometer confirm this estimate approximately, the value in one series of experiments being 10^{-9}. Although this is a small fraction, the accuracy of tuning is such that messages are sent between Burma and the Andaman Islands—a distance of about three hundred miles—with less than a horse-power.

Other Precautions.

To get such a result, precautions must be taken to avoid damping out the oscillations, not only by elevation even of the lower aërial above the earth, but by using appropriate conductors for these excessively high frequencies. To this end the wires are finely subdivided into insulated strands, and consist of a great cable or bundle of thinly insulated No. 40 wires, and the various self-inductions and other arrangements for effecting tuning are similarly wound. The tuning capacities are also arranged so as to be continuously adjustable, without pegs or discontinuities; and every kind of broken or uncertain contact is scrupulously avoided.

3. *Note on Oscillograph Study of Duddell Arcs of Low Frequency.*[1] *By* J. T. Morris.

4. *Developments in Electric Incandescent Lamps.*[2] *By* Leon Gaster.

5. *The new Engineering Laboratory at the City and Guilds of London Institute, Finsbury.*[3] *By* Professor E. G. Coker, *M.A., D.Sc.*

The recent extension in the Department of Mechanical Engineering at the City and Guilds Technical College, Finsbury, has been provided for by the City Companies aided by a private donor.

A new wing has been added to the College, in which accommodation has been found for an engineering laboratory, drawing-offices, lecture and preparation rooms. The principal feature of interest is the engineering laboratory, of about 4,000 square feet in area, on the basement floor. A part of this laboratory has been devoted to hydraulic equipment, which is mainly grouped with reference to a cast-iron channel, 80 feet long, and of square section 2 feet side. At one end of this is a space for a vertical pressure cylinder, for experiments on jets, impact on vanes, and the like. At the other end are measuring tanks, of a total capacity of 3,500 gallons, into which the water drains after passing over a weir in the main channel. There are also two subsidiary channels, parallel to the main one, and draining directly into the measuring tanks. The water after use is raised to

[1] Published in *Electrical Review*, August 9.
[2] Published in *Electrician*, August 23.
[3] Published *in extenso* in *Engineering*, August 16.

a roof tank of 5,000 gallons capacity by a centrifugal pump of 200 gallons capacity per minute, and it is returned to the laboratory by a falling main for use anew.

The hydraulic machines already installed comprise an inward-flow pressure turbine, an outward-flow Girard turbine, a Worthington pump, a three-cylinder hydraulic engine, and a considerable amount of other apparatus for experimental work.

The heat engines are all of moderate size, and are in most cases of special design for experimental work.

A gas engine of 12 horse-power is fitted for work with either town gas or suction gas from a Dowson producer. A refrigerating plant is arranged to work with either carbonic acid or ammonia by using interchangeable cylinders. An oil engine, hot-air engine, steam engines, and a compound air-compressor are also installed, while space has been left for future developments.

The equipment also includes a 10-ton Buckton testing-machine and a varied collection of other apparatus for testing materials.

The drawing-office has accommodation for a hundred students, and is divided by a glazed partition for convenience in teaching.

The workshops have been entirely remodelled, and nearly all the old machine-tools have been replaced by new ones.

A new lecture-theatre seats a hundred students, and is fitted with the necessary appliances for experimental and lantern demonstrations.

TUESDAY, AUGUST 6.

The following Papers were read:—

1. *Ferro-concrete and Examples of Construction.*[1] *By* J. S. E. de Vesian, *M.Inst.C.E.*, *M.Inst.M.E.*

The author referred briefly to the various kinds of materials that have been used for constructing buildings from early days, and showed that ferro-concrete was the most rational method, as in the Hennebique system the disposition of concrete and steel allowed of the maximum inherent strength of the two materials being made the utmost use of—that is to say, that the steel takes up all the strains due to tension, while the concrete bears those due to compression. In this manner one square inch of steel (say in the tension area of a beam) will interest 30 square inches of concrete on the compression side; and when one thinks of the different cost of concrete and steel, the economy is at once apparent. Not only is this method economical, it is also extremely durable and fireproof. The importance of careful selection, of mixing, and treatment of the concrete was shown, and the specifications for this, as well as for the steel, set forth.

The author insisted on the test of reinforced concrete buildings, shortly after construction, with a load of 50 per cent. in excess of the calculated load.

The behaviour of Hennebique ferro-concrete under stresses shows that this is really a *new* material, as its behaviour is so different from that of the concrete and steel separately.

Perhaps one of the most marvellous uses of ferro-concrete is in the manufacture and use of piles. It seems a strange fact that a loose frame of steel bars and a concrete setting can be made which one can drive into the ground better than any timber piles.

An important point which is often raised is the protection afforded to the steel by the concrete, and this the author mentioned, giving as an instance the head of a pile which had been cut off and left on the foreshore, where it was uncovered and covered by the tide for over nine years, and in which the steel showed as good as new a quarter of an inch under the skin of the concrete. This pile-head was brought up and broken in the presence of several eminent engineers the year before last.

[1] Published *in extenso* in the *Contract Journal*, August 21.

The impossibility of drawing up fixed rules for reinforced concrete constructions generally by corporations and municipalities was referred to. The chief safeguard to be employed is that of stringent tests after the construction is finished. In cases where much vibration is feared, from running machinery or other causes, ferro-concrete is admirably adapted to minimise the trouble.

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2. *Some new Uses for Reinforced Concrete.*[1] *By* W. Noble Twelvetrees, *M.I.Mech.E.*, *Assoc.M.I.E.E.*

So many papers have been read of late discussing the general principles governing the design of reinforced concrete structures and describing works of familiar character in which reinforced concrete has been adopted as the material of construction, that the author thought it well to follow a less frequented path.

Under the heading of 'New Uses for Reinforced Concrete' he considered some types of construction that have not yet been applied in this country, others that have been adopted only recently, and others again that are not new in themselves, but are very suitable for employment in novel directions.

In the first category may be placed such constructions as railway sleepers, standards for overhead electric cables in power transmission and electricity distribution systems, and poles for telegraph and telephone wires. The paper contained particulars relative to the design, construction, and application of such accessories as these, which are now coming into general use on the Continent and in America.

In the second category was considered the employment of reinforced concrete to dock engineering, as illustrated by the Scotstoun Dock on the Clyde—the first example of its kind in Great Britain; of coast defence and harbour works, as illustrated by the sea wall and protective slopes at West Hartlepool, groynes near Brighton, and a breakwater near Waterford; and of long-span bridges for main-line railway traffic and for crossing important rivers, as exemplified by typical structures in this and other countries.

In the third category the author indicated the special advantages to be obtained by the adoption of reinforced concrete as a material for the construction of railway-station roofs, locomotive depôts, and bridges over railway lines. In all such structures steelwork is particularly liable to corrosion by reason of its exposure to steam and destructive gases from locomotive engines and boilers. To illustrate the adaptability of reinforced concrete to these new uses, the author gave brief particulars of roofs that are akin to those generally built in steel for covering railway stations, of a locomotive depôt erected on the Jura-Simplon line, and of highway and foot bridges over railway lines.

Finally he alluded to the method successfully adopted on the Continent for preserving steel bridges by encasing them in concrete, a course that is commended to the attention of railway companies and highway authorities in places where the corrosive effect of locomotive fumes is a constant source of trouble and expense.

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3. *The Origin and Production of Corrugation of Tramway Rails.*[2] *By* W. Worby Beaumont, *M.Inst.C.E.*

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4. *Modern Machinery and its Future Developments.*[3] *By* H. I. Brackenbury.

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5. *Resistance Coils and Comparisons.* *By* C. V. Drysdale.

This paper dealt with the existing forms of standard resistance coils and of standardising bridges, and with some new forms of standard coils and testing

[1] Published *in extenso* in the *Builder*, August 24.
[2] Published in *Engineering*, August 16 and 23.
[3] Published in *Engineering*, August 30.

arrangements devised by the writer. A short account of previous tests on resistance alloys was followed by a description of some recent tests on modern resistance materials obtained by Mr. J. H. Baugh and tested by Mr. A. C. Jolley in the laboratories of the Northampton Institute. The alloys best suited for standards, owing to their low temperature coefficient, are those of copper and manganese, or of copper and nickel. The former has the advantage of low thermo-electric force against copper, but a very curved temperature variation. The copper nickel alloys, on the other hand, have a nearly regular temperature coefficient which may be either positive or negative, but their thermo force is very high.

The desirable features of standard coils were mentioned, emphasising the matter of low and uniform temperature variation and good heat radiation, and it was pointed out that most existing standards are deficient in these respects and in the design of their terminals.

The author proposed an open wound coil with special form of terminals, and wound with a wire of copper nickel or similar alloy, in which the temperature variation is compensated, either by joining two such wires of positive and negative coefficient in series or in shunt with each other, or by coating a wire of negative coefficient with a suitable proportion of a metal or alloy having a positive coefficient. By suitable selection it may be possible to compensate both the first and second terms in the temperature variation. It has been found possible in this way to obtain a coil having a temperature variation probably less than one part in a million for 1° Centigrade over the ordinary working range of temperature.

The bridge method either in the single or double form was considered best for standardising purposes, and a comparison made of the slide wire bridge in its various forms with that of the Reichsanstalt. A description was given of a new bridge in which the advantages of both forms have been combined, this bridge being capable of being used either as a single or double bridge for resistances of any value, with or without potential contacts, and of any gauge. The readings can be taken either by shunting or on a double slide wire, and in the latter case the difference between the coils is read directly over a range from 1 to 5,000 millionths. A special form of ratio coil, enabling step-up or step-down measurements to be made, was also described.

WEDNESDAY, AUGUST 7.

The following Papers were read:—

1. *A Machine for Weighing the Forces on a Cutting Tool.*[1] *By* John F. Brooks.

The object of the machine is to measure the three co-ordinate components of the force on a cutting tool while in the act of cutting metals.

The tool, fixed in a holder, forms part of a simple lever carried by a thin diaphragm of steel.

This device gives a universal frictionless pivot when used for very small displacements.

The location of the lever is effected by means of electrical contacts in circuit with telephone receivers.

Weights are used to balance the forces.

The apparatus is capable of measuring maximum, minimum, as well as mean, values.

The position of the centre of pressure may be found by two or more experiments.

The paper was illustrated by diagrams, showing the values of the forces on tools with cutting angles of 65° and 70° when cutting cast iron and mild steel, with small cuts at moderate speeds.

[1] Published *in extenso* in *Engineering*, August 23.

2. *Notes on the Governing of Hydraulic Turbines.*[1] *By* ROBERT S. BALL, *Assoc.M.Inst.C.E.*

This paper dealt with the problems involved in the speed control of hydraulic turbines for the range of head of 2 to 3,018 feet, under which turbines are at work throughout the world, and was particularly intended to apply to hydro-electric installations. All hydraulic regulators may be divided into two classes as follows:—

(1) Disengagement governors (mechanical), which come into action when an assigned departure from the normal speed is attained, being otherwise out of gear with the gate-controlling mechanism.

(2) Continuous governors (mechanical and hydraulic), which are always connected to the gate-controlling mechanism and which begin to operate through the mechanism upon the gate at the moment the speed rises or falls from the normal.

Mechanical governors are of many kinds, such as the Hartford, Gilkes, Replogle and others described in the paper, all of which operate upon the controlling gates through a system of gearing or mechanism actuated by the pendulum governor. The power to drive these governors is taken from the turbine usually, but is also sometimes obtained from an independent source, as in a large hydro-electric installation. Hydraulic governors are so called because water or oil under pressure is employed in closed cylinders to actuate the gates, the valves being controlled by the pendulum governor. These governors take various forms, such as the Bell, Gilkes, and Escher Wyss, according to the type of wheel they are set to control. Where the hydrostatic pressure is sufficient it is used directly in the hydraulic cylinders, but for turbines working under low falls auxiliary oil-pumps are used to provide the necessary pressure for actuating the water gates. There are three forms of gate to which governing mechanism is applied: (1) movable turbine vanes; (2) a circular gate between the runners and the guide vanes; (3) nozzles such as are used for Pelton wheels and other impulse turbines acting under high heads.

The function of the fly-wheel, as distinguished from the governor, was discussed, the former being a mode of keeping the angular acceleration low when the balance is upset between the driving torque and the resistances opposed to it, while the latter is intended to re-adjust the balance. The cyclic variations of angular velocity encountered with some forms of heat engine, especially the internal-combustion engine, are absent in the hydraulic plant, which results in a saving in the flywheel capacity, though for impulse turbines it is sometimes necessary to increase the moment of inertia by the addition of a fly-wheel.

The action of hydraulic governors was described and the paper illustrated by eleven figures and diagrams plotted from the results of tests.

3. *The Ice Problem in Engineering Work in Canada.*[2] *By* Professor HOWARD T. BARNES, *D.Sc., F.R.S.C.*

In Canada the physicist has excellent opportunity to study on a grand scale the operation of the natural laws governing the formation of ice in the many forms met with in the large and often turbulent rivers. To the engineer the problem is more serious, for the development of the vast water powers of the country must include means for combating the ice troubles which arise each winter. The conditions which must be met during the winter months are sometimes very serious, when ice is forming rapidly, and ice-bridges, dams, and shoves may change the whole character of the levels and channels in a single night. Rivers are known to have been turned entirely out of their course to seek new channels during a winter of unusual severity, and in some instances the reversal

[1] Published *in extenso* in *Engineering*, August 16 and 23.

[2] Published, with illustrations, in *Engineering*, August 9.

of a rapid is of yearly occurrence. Nowhere can one witness a more wonderful sight of the delicate poising of the forces of Nature than in one of the Canadian rivers in winter. The steadiness of the temperature of the water throughout the ice season is a matter of great interest. It seldom varies more than a few thousandths of a degree from the freezing-point even in the severest weather. This is true for rivers flowing too swiftly for surface ice to form, as well as for the quieter streams protected by an ice covering.

In general, three varieties of ice are distinguished and present characteristics brought about by their method of production. Surface or sheet ice forms over the surface of quiet lakes or rivers, and is helpful or not depending on the particular conditions. Spicular ice, or as it is called in Canada, frazil ice, is formed by surface agitation in the more turbulent rivers, and in waterfalls, and accumulates in great quantities in the quieter portions of the stream where it is carried by currents. It varies in size from thin plates to fine needle crystals depending on the degree of agitation of the water, and of all the forms of ice it gives the most trouble in hydraulic work. Anchor- or ground-ice is the most interesting form, on account of the fact that it grows along the bed of a river which is not covered by a surface sheet. It is formed in two ways: by the cooling of the bottom by the radiation of heat during cold clear nights, and by the freezing of frazil-ice carried down by the currents of water when in a super-cooled state. A bright sun has a great influence on the ice, and as soon as its rays are sufficiently high to penetrate to the bottom, the ice is detached and rises to the surface. In so doing it frequently brings up stones or boulders of considerable size to which it is attached.

A study of the temperature conditions in the water during the production of these forms of ice shows that the freezing is accompanied by a small temperature depression in the water, amounting to a few thousandths of a degree from the freezing-point.[1] During severe cold weather the water is thus thrown into a slightly super-cooled state, during which time the ice crystals grow rapidly by continued freezing, and give rise to the agglomerating stage, when they possess adhesive properties and form lumps and spongy masses. In this condition the ice is dreaded by power users, for it quickly adheres to the rack-bars and to the machinery of the wheel-gates and turbines. In a short time it interferes with the operation of the wheels, and may at any moment cause a temporary cessation of operations. Fortunately, it is only a minute temperature depression which brings about these conditions, and methods of artificial heat applied about the affected spots relieve the situation in a short time. An intelligent use of artificial heat, especially at night time when supercooling is most common, is found valuable in preventing any interference with the normal operation of a power-house. It is not necessary to warm the entire volume of water passing through, which would be very costly and difficult, but by applying the heat in the racks or wheel cases, or blowing steam about the affected parts, the ice is prevented from obtaining a foothold. The ice is as effective as so much water in producing a head, hence the necessity of passing it through, and never allowing it to freeze to the metal surfaces of the machinery. It is safe to say that where it is possible to apply even a small quantity of heat directly to the machinery and racks, a condition of affairs may be done away with which for many years has been regarded as involving inevitable interruption to the continuous operation of a plant.

There are other causes at work, however, to interfere with the operation of power plants which depend on the particular spot where a power-house is located. Rivers like the St. Lawrence at Montreal are subjected to winter floods, occasioned by the accumulation of frazil- and disintegrated anchor-ice. Wherever open water or a rapid occurs above a surface sheet of ice, large quantities of frazil-ice are carried under by the currents, and settle upwards in the quieter parts. Large hanging dams of spongy ice are thus produced, which so reduce the available waterway as to cause serious changes in level. Sometimes the channels become blocked entirely, and then the water backs up sufficiently to clear the ice

[1] Cases are known, however, where anchor-ice was formed by copious nocturnal radiation when the water was slightly above the freezing temperature.

away and produce a shove. A tremendous upheaval results, and large masses of ice are piled on high for miles around, often doing much damage.

It is well known that the most effective prevention to the formation of both frazil- and anchor-ice is the protection afforded by a surface sheet of ice. If a power-house is located on a river normally frozen over, with no stretches of open water above, no ice troubles are experienced. When this is not possible, artificial intake canals are usually constructed, in which the water flows sufficiently slowly to freeze over. If the canal is fed from the open river, booms and crib-work are resorted to in order to deflect much of the ice. If the inflowing water-current is sufficiently rapid to draw the frazil under the surface ice, it is often necessary to cut artificial channels to allow of sufficient water for the wheels. Thus a surface sheet may prove to be disadvantageous. So many and varied are the conditions to be met with in the location of a power-house that no set of rules can be given to meet the general case. It is only by a thorough knowledge of the laws underlying the formation of ice that means may be found to cope with any particular situation. It may safely be said, however, that the ice problem in Canada is no bar to the future development of her vast water-powers.

4. *On the Application of Water Power, and how to secure the greatest Efficiency in its Working.*[1] *By* JOHN SMYTH, *M.A., M.Inst.C.E.I.*

The author showed that a great many falls of water are not now made use of because they are too small or the supply of water is too irregular, but that they may become valuable by supplementing the water power by means of a variable auxiliary power. On the Upper Bann River, in the North of Ireland, there are a number of these small falls, and the author described one where the normal quantity of water, as maintained by the Reservoir Company, only produces through the turbine 7·2 horse-power to the foot of the fall; but having made the turbines of sufficient capacity to take and use the winter and flood flow of the stream, an average of 11 horse-power is obtained, making a distinct gain of 3·8 horse-power, equal to 19*l.* per annum, as compared with steam power for a drive of ten hours per day. In the case described a steam engine is used as the supplementary power, since it is specially suitable to the work done in that mill. Any other motor, however, such as an oil or gas engine, would do equally well, according to the nature of the work to be done.

The author would also make these falls more valuable by the construction of compensating or subsidiary reservoirs or lakes on poor lands along the course of each river, into which floods might be drained or impounded and gradually withdrawn afterwards to the lower reaches for the use of the mills.

This would have the further advantage of diminishing floods, and would not interfere with the construction of reservoirs on the higher grounds, where the water is purer for the supply of towns, and thus the full advantage would be taken of the entire drainage area of each river.

In a paper read before this Association in 1874, at the Belfast meeting, on the industrial uses of the Upper Bann River, and published *in extenso* in its Report, the author mentioned one such reservoir which had then for many years been of great service to the mills. It is still doing the same good work.

The author believes water-power is not sufficiently valued by engineers and millowners because of the inefficient water motors so long in general use, but there is no difficulty now in procuring motors to give 80 per cent. of the full power instead of from 30 to 70 as heretofore.

[1] Published in *Electrical Review*, August 23.

Section H.—ANTHROPOLOGY.

President of the Section—D. G. Hogarth, M.A., F.S.A.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

Religious Survivals.

The science of Anthropology, from its very nature, seldom touches the beliefs or customs of the higher actual civilisations; but exceptions occur when it enters the field of comparative religion. In coming to the aid of this fascinating study it can hardly help offending, sooner or later, certain prejudices which are deeply rooted and widely distributed, and that not only when it really contravenes the beliefs of pious minds, but, often enough, when its exponents neither wish to impair these beliefs, nor, as a matter of fact, are taking any steps to do so; for the opposition which meets science when it concerns itself with religion is very frequently arrayed before the opponent has taken the time or the trouble to ascertain whether anything vital or essential is concerned in the investigation. At any rate it will be allowed that the majority of the treatises on this study written in the English tongue do not, by any lack of reverent treatment or by any obvious oblivion of the responsibility resting on those who inquire into the religious basis of our social order, display any desire to offend. But just because some offence must almost inevitably be given, even by the most reverent anthropologist, in pursuing investigations which involve examination of actual pious beliefs, it is especially incumbent on students of this particular subject to proceed only along the most strictly judicial lines, careful not to force a conclusion from evidence which is in any respect dubious or even incomplete; and, moreover, to be quite clear in their own minds and to make it clear to others how far their investigation really touches actual religion in vital and essential points of belief as distinguished from mere points of observance or ritual, *i.e.*, religious accidents, as they might be called. Obvious as this caution may seem, neglect of it is very general, and has led to much needless suspicion of Anthropology as a science with covert and far-reaching purpose, subversive of all religion.

It is in the interests of definition and clearness (in a controversial topic among the religious inquiries of anthropologists) that I have chosen my theme to-day. I have small claim to expound the science, as usually understood, to which this Section is devoted, whether on its physical or on its social side, so far as the latter is principally concerned with actual custom and folklore. But as one who has spent more than twenty years in studying the ancient life of that region of the world in which three of the greatest actual systems of religion were developed, and a good part of his time among the modern peasantry of the region itself, I have had my attention particularly directed to the evolution of religious beliefs and observances during long periods of time, which are unusually well illuminated for us from first to last by the light of both monuments and literature;

and that attention has often been arrested by striking instances of *cultus* continuity under successive religious systems or dispensations. I enjoyed the advantage of beginning travel in the Nearer East in the company of the acute observer who is now Sir William Martin Ramsay, and to his comments on what we saw together in the Phrygian highlands as long ago as 1887 I owe much of my earliest interest in the question of religious survival and my direction towards the lines on which I have since tried to study it. Some day let us hope that, prompted by such a lectureship as the Gifford Foundation, or encouraged by some discerning publisher, Sir William Ramsay may collect from his many books the scattered observations upon the religious elements which survived from Anatolian heathendom into both Christian and Moslem observance, and adding to them others from the storehouse of his memory and his note-books, produce a volume parallel to that 'Religion of the Semites' which is the abiding memorial of his dead friend and ally.

I have called 'Religious Survivals' a controversial topic. That is to put it mildly. Indeed, few anthropological topics generate so much heat. In addition to a common distaste with which one may sympathise, even if one does not share it, manifested by many reverent minds for all objective discussion of things religious, this topic challenges a certain very widespread prejudice, as irrational as it is strong—namely, the prejudice against the inclusion of orthodox religious beliefs and observances under the general maxim, 'There is nothing new under the sun.' The more sacred a man holds anything the less will he believe that evolution has had anything to do with it—evolution with its inevitable implication of embryonic and imperfect stages. The Athenian loved to think that the great patron goddess of his city sprang fully grown and fully armed from the head of the King of heaven. The devotees of all creeds have wished to believe that when the first founders of systems proclaimed their missions the old things passed away like a burning scroll and a wholly new earth and heaven began. Nothing is more repugnant to the ordinary orthodox Moslem than the suggestion that the Prophet borrowed theology and doctrine from earlier Semitic systems, notably the Hebraic, and that much of the ceremonial and observance now followed by the faithful in their most religious moments, those of the Meccan pilgrimage, survive from the times of ignorance. Yet what contentions are less controvertible in fact than these? The devotee can believe that every detail of a new dispensation was known from all time in heaven, but will refuse to allow that anything can have been known on earth. With that direct revelation which he thinks to have been vouchsafed at a given moment from on high, the slate of time must have been wiped clean of all previous religious thought and practice. I do not, of course, speak for one moment of the enlightened and scholarly doctors of our own creed or any other. These have always seen and often stated that the religious systems by which they hold have assimilated much from systems of earlier date; nor in admitting that have they found their faith take any harm.

How natural and compelling, however, is the prejudice in question may be estimated by the fact that it is extended to dispensations in other fields than the religious. For example, that message to civilisation which it was given to the pagan Hellene to deliver does not admit in the view of certain devout Hellenists of the view that the Greek artistic sense had any pedigree in pre-classical times. They resent as an insolent innuendo the contention that what is essential in the Greek spirit can be detected in the work of peoples living in the Hellenic area long before the rise of classic Hellenic art, and that from these peoples and from others who possessed older civilisations the fabric of Hellenism was built up in strata, which can still be observed, and referred to their pre-Hellenic authors. So close akin is *odium archæologicum* to *odium theologicum*! Yet, perhaps, in this case they are really one and the same, for perfervid Hellenism is the last half-conscious protest of the Western peoples of Europe against the dominance of an Asiatic religion.

Irrational is this prejudice in the first degree of course, because not only have we the clearest historical evidence that in our own religious practice, as in that of other races, details of earlier ritual and observance have survived, often by con-

scious and intentional adoption, but also, as Robertson Smith well said, 'experience shows that primitive religious beliefs are practically indestructible, except by the destruction of the race in which they are ingrained.' All apostles of new creeds have had to preach to and gain the adherence of societies which they could not hope to lead to a perfect way all at once or even in centuries of time, and all have had to take account of pre-existing habits of religious thought and actual expressions of religious feeling, and by accepting some compromise to modify these to their purpose. And if this be obviously true of those societies which such an apostle as Mohammed could influence directly and retain under some sort of personal control, what must we say of the societies to which the truth only came at second hand or by many more degrees removed from the original prophetic utterance? What of the remote or scattered folk to whom it came not at all till after a long interval, and then faint and confused as a reverberating echo? For these at least there was no possibility of such utter change as revelation working through the human agency of a magnetic personality may have effected elsewhere; and of their belief and their practice much, perhaps the most, has remained primæval and local, and as the physical conditions of their life have prompted it from all time to be, and prompt still.

All this stratification in religious belief and practice it is the function of Anthropology to investigate; and thereby it may render no small service to religion itself by distinguishing accidental elements in ritual and observance which have persisted from systems worn out and abandoned. But while proclaiming that this investigation is not only legitimate but necessary, I wish to-day to utter a note of warning against a certain confusion of thought which is often manifested by the investigators in this particular field, and is apt to occasion unfortunate ethical consequences or, at the best, unnecessary scandal. It finds expression in the grouping of all the elements in belief, observance, and ritual, which have persisted from earlier systems to later, under one head as religious survivals, without due account being taken of very vital differences, both in their essential nature and in the history and reason of their persistence. The word 'survival' itself is *per accidens* not a very fortunate one. Though in the broad sense perfectly appropriate to all things that persist, it has acquired in our modern speech, largely from its use in medical science, a certain particular connotation of opprobrious import. It suggests something which has lost its useful purpose, and is effete or even dead, persisting among living organisms usually to their detriment. Such is the sense in which many anthropologists seem to use the word in speaking of religious persistences without discriminating between divers kinds of these; and such, still more often, is the connotation which their readers attach to the word in this connection. Yet all religious persistences are not survivals in this pathological sense —nay, the class to which this connotation is suitable includes but a small proportion of the whole. It is to distinguishing these classes of survivals that I propose to address myself in the remainder of the time which is allotted to me to-day.

In the first place there is a most numerous and important body of religious persistences which ought not to be called survivals at all, if that word be used, as it usually is, with a causative implication; that is to say, there are elements of belief and practice whose existence in actual cult is not necessarily due at all to the fact that they, or something very closely akin, existed in a previous cult. If religion is the expression of the instinctive desire of man to find an intelligible relation between his own nature and a nature which transcends its limitations, he appears unable to establish that relation by other than a very small and definite number of conceptions; and among certain races, and indeed in certain geographical areas, those conceptions seem not to vary over immense spaces of time and under successive dispensations. The just way to regard them, therefore, is as falling within categories of thought inevitably imposed on the human mind by its humanity and necessary conditions of any religious sense whatever. Man does not form these conceptions because his predecessors formed them, nor indeed because his contemporaries hold them; but because, as an individual limited by race and environment, he cannot otherwise satisfy his religious instinct. How important this class is, and how much it includes which

has often been discussed by anthropologists under the head of religious survival, may be judged if we recall that there falls under it such an article of belief as the Incarnation of God with all its consequences of expression—the immaculate conception, atoning death, and bodily resurrection. Neither this belief nor any of its expressions, I need hardly say, make their appearance for the first time in Christianity. They are to be recognised as forms—necessary categories of creed if you will—under which races of the Nearer East and of other regions of the world also have conceived the relation between the human and the divine as far back as we know anything of their history. But since anthropological knowledge concerning this delicate and difficult instance has been set forth lately in full detail by a distinguished student of religious persistences, Mr. J. G. Frazer, in his 'Adonis, Attis, and Osiris,' I feel no obligation to deal with it further than to remind you that, apart from all question whether Christian tradition states historical facts in this matter, nothing which Anthropology has collected in the way of comparative facts from other creeds serves to place either this belief or its form of expression among religious survivals in the narrower sense—that is to say, among religious elements which appear in Christianity merely because they existed in earlier religions. Much accidental circumstance has beyond doubt attached itself to this Christian tenet from the previous cult observances and ritual of the many races which it has convinced; and to certain of these I shall call attention presently when I come to deal with another class, more properly to be called religious survivals; but as for the essentials of the belief, they have as much right to be regarded as independent conceptions of Christianity, despite their earlier appearance in other religions, as history proclaims them to have been endued by Christianity with a wholly new ethical significance.

But in order to fortify my generalities with a particular example, I may be allowed to deal in brief detail with another, though related, religious conception of the same class, which has not been so exhaustively treated by anthropologists. As a student of Mediterranean races and a frequent observer of their actual representatives, I have often been struck by the persistent dominance of femi inity in their conception of the Divine, and equally by the distinction which that fact makes between their instinctive creeds and those of other races domiciled contiguous to them, but round an outer radius. In fact, it would not be difficult to draw a broad frontier line at a certain distance inland round the Mediterranean area from the Atlantic to the African deserts, within which a Goddess has always reigned supreme in the hearts of the unsophisticated folk, with a God occupying only a subordinate, and often demonstrably a less primæval, throne; while without it the God has been dominant and feminine divinity secondary. Within the frontier lie the peninsular and other littoral districts with a broad *hinterland* of mountainous or hilly regions. With the great continental plains begins the outer and contrasted circle. The predominance of a great Nature Goddess among all the races of the East Mediterranean basin in the earliest historic time is well known; and to what had been ascertained of her among the Semites, under her many names, Tanith, Al-Lat, Baalit, Ishtar, Atta, Ashtaroth—these last but variants of one appellation; among the Nilotic peoples also under many names, *e.g.*, Neith and Isis; among the Anatolian races as the Great Mother, Kybele, Ma, and the unknown 'Hittite' title; among the historic inhabitants of Greece and the Ægean as Rhea, Artemis, Britomartis, and a score of other appellations; among the Italic tribes, as Diana or local variants, there has been added latterly the discovery that a Goddess of character and attributes, readily to be compared with those of the Nature deity in various parts of the surrounding area, was dominant in the religion of that important artistic race which occupied the Ægean in the prehistoric age, and had so much influence on the momentous civilisation of its later time—that race which has been rescued from long oblivion by Schliemann in Greece and Troy, and by Evans and others in the Isles. The more we learn of this great Nature- or Mother-Goddess, the more primæval and predominant is the position she is seen to hold. All round the Eastern Mediterranean she was before all created things: she became the mother of a son by spontaneous generation or some other process independent of

the male—an idea, it may be remarked, which presents no impossibility to the minds of very primitive races, some of whom even at this day do not connect fertilisation and conception as cause and effect. With her son she produced all life: she gave her son to the humanity so created, and humanity killed him that it might live; he revived and returned again to his mother, was again killed, and so the cycle of the seasons revolved. So far as concerns Him in all his *avatars* Mr. Frazer's book may be consulted. As for Her, a Woman still holds the same place in the religious belief of the old races of the same region, wherever they have escaped assimilation by conquering races and faiths from beyond the border. Hear any Greek or Italian peasant in a moment of excitement or danger. He calls on no Person of the Trinity, but on the Virgin. For him her power does not come from her Motherhood of her Son. Indeed, I have known Christian countrymen of a West Anatolian valley to whom that motherhood was evidently unknown, and when spoken of remained without interest or significance. She is a self-sufficient, independent embodiment of divinity, to whom the ruder folk of Mediterranean lands offer their prayers and pay their vows alone. She and no other is beseeched to grant increase and fertility; she and no other is credited with the highest direction of human affairs. But to say, as so often is said, that, for instance, in Greek lands the Panaghiá is simply a survival of Artemis or Aphrodite under another name, is to convey a false impression. She stands for the same principle of divinity as they; she has taken on, as I shall point out presently, even the feasts and the ritual of her predecessor; and she has often made peculiarly her own the spots especially sacred to the earlier Mother-Goddess. But, as I take it, she is not worshipped now in Ephesus or Cyprus merely because there was once a dominant cult of Artemis or Aphrodite in those places, but because to the peoples of a wide Mediterranean region it is still, as it always was, a religious necessity to embody their idea of divinity in the feminine; and I would state the relation of the Christian Virgin-Goddess to the pagan one rather in this way—that, coming from without, she gained acceptance at once for herself, and probably also, in a great measure, gained acceptance for the whole creed with which she was connected, because she offered a possible personification of the same principle which had always been dominant in the local religion.

Why that principle was so deeply rooted in the peoples of this particular region I cannot pretend precisely to say. To ascribe it, as has been suggested, to the original prevalence of *Mutterrecht* is probably to mistake effect for cause. The principle has its roots deeper down than even the matriarchal system. In a general way we may hold it the result of a peculiar mental concentration upon the idea of generation and reproduction of life, upon the increase of man, the brute creation, and the earth. In these processes the more obvious part played by the female in Nature inevitably tends among primitive peoples, who are comparatively peaceful and more of agriculturists and herdsmen than warriors or hunters, to make woman seem the sole condition of their being and the predominant arbiter of their destinies. More we can hardly say. We cannot determine whether there were peculiar geographical conditions in the dawn of time, which, either in some other home or in the Eastern Mediterranean region itself, predisposed the ancestors of the actual races of the latter to this cult of the reproductive force. One can but bear witness that at the present day this idea is an obsession of these inhabitants wherever they remain in a comparatively simple state of society. All their thoughts, their prayers, and their actions seem to be inspired by it, and of all their thoughts, their prayers, and their actions—so far as they have not been warped to the Father-God of the Southern Semites by the armed pressure of an alien folk from the warlike steppes of Northern Asia—Mary, the Panaghiá, is the focus.

In her essential identification with the religious sense of these peoples, therefore, the Virgin is no mere survival. But in an accidental or secondary sense her actual personality may, perhaps, be so regarded in the region in question if we are careful to exclude from the word all connotation of superfluity or decaying energy. Her cult may be brought under that body of beliefs, observances, and practices which have demonstrably passed from earlier religious systems to later

by processes of transference, usually unconscious, but often half-conscious, and undoubtedly in some cases wholly conscious. Where the process has been unconscious or half-conscious these beliefs, observances, and practices have survived in the new system because the religious sense of the masses felt instinctively that they were necessary to its expression. They cannot therefore be regarded as survivals with any implication of decay or death. They were necessities under the former system; they remained necessities under the later, and may be living forces and vital expressions of the human desire for relation with the divine under the new as much as under the old. Where the process has been conscious a popular demand for their survival as necessities has been appreciated by leaders of the system, and observances and forms of ritual have been consciously taken from the old system to express a principle still active under the new. Often we are in a position to know that the old beliefs, observances, and forms did not accord with the highest ideals of the most advanced professors of the new system, and that they came to be consciously adopted by compromise in the interests of the more rapid and permanent establishment of the latter among inferior intelligences. They were better than the worse, if not as good as the best. Of these Dr. Bigg is speaking in the preface to his book 'The Church's Task under the Roman Empire' when he says, 'The most significant changes in history were not imposed upon the Church by the bishops from above, but forced upon the bishops by the pressure of popular opinion from below.' A well-known example is supplied by the early history of Islam, when the Prophet, having learned in exile at Medina, what many of his apostles have since had to learn, that the Semitic masses could not be weaned to a perfectly spiritual system, came to terms with the primæval worship of the Arabian Goddess in Mecca and displaced her personality by retaining many expressions of the popular cult of her; and, as so often has happened in similar cases of religious transference, those expressions remaining to this day the most strictly observed by Moslems, testify still to the vitality of the religious necessity which lay and lies behind them. And not only the early history of Islam, but the early history of Christianity offers instances of such conscious transference, some of which may be read of in Sir William Ramsay's works, *e.g.*, in 'The Church in the Roman Empire,' where he deals with that strange story of Glycerius the Cappadocian deacon, who broke out at a certain great gathering of Christians at Venasa, one of the holiest of the pagan high places of the land, and revived the former orgiastic form of cult by leading a band of enthusiastic maidens dancing and singing through the hills to the glory of Christ crucified. Condemned in haste by the stern Basil of Cæsarea, the recalcitrant deacon found an apologist and a protector in no less saintly a priest than Gregory of Nazianzos, who knew better than his Metropolitan how real and deep a local religious instinct lay beneath this scandalous manifestation, and how much better it were to bend to the service of the Church, than to break, the religious zealots who had expressed it. Another curious collection of such transferences may be found in a recent work of Mr. Rendel Harris, which he entitled 'The Heavenly Twins.' Here are set out an immense number of facts and suggestions tending to show how the early Church adapted to its ends the cult of the Dioscuri or of similar twin gods known by other names both in the West and East, a cult which expressed a certain conception of the relation between human and divine, salutary and indeed necessary to many pagan minds. The book needs to be read in a critical spirit, for the author has been led on by the fascination of myth-interpretation to find his twin nature-gods wherever he turns to look for them; and often his reading of the legends is less convincing than would be (if it is allowed to use a frivolous instance in such a connection) a similar explanation applied to the story of Box and Cox—those obvious twins of Dark and Light who occupied, turn and turn about, their chamber, the World, under the benign influence of the landlady of the tale, a manifest Earth-Mother of mythology.

Many of the undoubted transferences which took place under the Christian system cannot at this time of day be certainly distinguished into the conscious and the unconscious. We know that saints of the Church have entered often into the honour and the local habitations of pagan deities. Mr. Frazer has told us

how St. Felicita has replaced Mephitis, the heathen personification of the poisonous gas of the pool of Frigento, and how Adonis in Sicily and Sardinia lives on as St. John. These instances might be multiplied to many hundreds. We know, too, that almost all our stated ecclesiastical festivals are continuations of heathen feasts, so far as their dates and the general nature of their commemorative significance are concerned. What had to be changed has been changed, but not more. Christmas has succeeded to the festival of the winter solstice which celebrated the new birth of the Sun; Easter to the spring festival at which in many parts of the Mediterranean world the Nature-Goddess, and especially the death and resurrection of her Son, were commemorated. The Assumption of the Virgin replaces the August feast of Artemis and Diana in Greece and Italy. The anniversary of St. George, so great a day in modern Greece, seems to be the old Parilia; St. John the Baptist has taken on the heathen rites of midsummer, and you may see the folk of Smyrna, Christian and Moslem alike, jumping through fire to his honour on any St. John's Eve. Very rarely, as in the case of the Feast of All Souls, the late Christian adoption of which in the tenth century happens to be known, can we ascribe these transferences to any definite action of a leader of the Church. Usually we know no more than that where and when there was once a pagan saint or a pagan feast there are now saints and feasts of Christianity. But no reasonable person feels that the latter are discredited or lose anything of their actual significance by the fact of their having a pre-Christian pedigree. St. John may have succeeded to Adonis, but he is not Adonis. Christmas may be the heir of the Saturnalia, but it is the Saturnalia no longer. To feel that the sanctity of either is impaired by these facts is as if one were to refuse reverence to the art-types of early Christianity, because most unqestionably these were not invented fresh and new for the new religion. Why should they have been? If there were ready to hand images in pagan art, fit to express the early Christian ideas, it would have needed a miracle for the nascent Church to have invented new ones. The human creative faculty in matters of art is strictly limited as to types. Presentations of Apollo or Orpheus were used naturally for the new Christ, and those of the Nature-Goddess of Asia with her Son for the new Mother and Child. How else should gracious maternity have been represented? Last year I showed in this Section certain terra-cotta images of the Ephesian Goddess with her child, dated to the fourth century before Christ, which might easily have been mistaken for Madonna figures of the Italian Renaissance; and last winter I saw in a newly excavated Coptic chapel of the sixth century at Memphis a fresco painting of the Virgin suckling her Son which was indistinguishable from late representations of Isis.

As a matter of fact there is little fear that anthropologists in demonstrating the fact of transference in such categories of religious expression as these with which I have just been dealing will impair their religious efficiency. For, after all, how much is there not in the everyday expression of the religious sense among ourselves which has suffered a transference in time and space so obvious that no reflective mind can be unconscious of it? Consider only the religious phraseology current among the simplest Christians—all that mass of images and ideas proper to an alien race and to the latitude and climate of the Mediterranean in which, for example, the Presbyterian of Scotland expresses the most pious of his aspirations. He sighs for the shadow of a great rock in a weary land, for the plash of running waters, for the shade of the fig and the vine; and, the most restless of men to whom all inaction is hateful, he aspires to a heaven floored with the crystal of Oriental imagery, where he shall for ever sit still. These ideas one meets at every turn, not only in the religious, but in the secular, thoughts of every Oriental or South European. Among us they appear in religion only, known for manifest exotics, but not the less full of religious significance, even to the least congruous Christian.

Ere I leave this second class of Survivals let me revert again for a moment to the cult of the Virgin in the Nearer East. It is possible, even probable, that Mary, the mother of Jesus, also owes her divine, or at least semi-divine position in the Christian system to such a conscious effort by leaders of the Church as those to which we have just alluded. It is a well-known fact that neither the

primary nor the secondary authorities for the first two centuries of Christianity supply any warrant for the position which she was to hold later. They are, in fact, almost silent about her. Nor has Christian archæology discovered any better evidence of her glorification above other holy women during that time. It seems established that it was not till the third century that she began to assume semi-divinity. By the fourth her position was sufficiently exalted to cause the schism associated with the name of Nestorius, whatever the real views of that ecclesiastic may have been; but it was not till A.D. 431 that she was officially acknowledged by a General Council to be divine in virtue of her Theotokiá, her Motherhood of God. It is difficult not to believe that this is one of the examples of the general fact which I have just quoted from Dr. Bigg, and that the bishops assembled at Ephesus on that occasion were tardily conceding a demand for the recognition of the feminine principle in divinity, made ever more and more openly by the voice of the common people all round the Eastern Mediterranean. We are told indeed in a contemporary letter written by one present in Ephesus at the time that the populace of the city itself, that immemorial seat of a Virgin-Goddess, gathered about the church while the Council was sitting, and put pressure on the bishops when they showed signs of wavering in their decision to proclaim the Theotókos by condemning Nestorius; and that when the decree had at last gone forth the Ephesians went wild with joy. Their Great Mother had come again to her own.

Once established, or, more probably, little by little while she was gaining recognition, the Christian Virgin appropriated the festival dates, the holy places, and even the rites of her predecessor. Here we approach a third class of survivals. The great August feast of Artemis, as I have said, became that of the Assumption of Our Lady; temples, groves, sacred springs, and other holy spots of Nature-worship were transferred to the new patroness of all life and fertility. There are hundreds of places in Anatolia, Greece, and Syria which might be called to testify. One of singular interest I visited a few years ago, that wild spot in the Lycian mountains where the ever-burning gaseous flames of the Chimæra break out in a clearing of the forest. Here, on the foundations of a temple, stands the ruin of a church built over the largest vent of the fire. Islam has decreed that the goddess of the earth-flames be no longer openly adored, but all the bushes which grow about the ruin I found hung with mouldering rags of quite modern date, witnesses that her cult is not yet dead in the hearts of shepherds and woodmen. On the wall of a ruined convent hard by is a half-effaced fresco of Mary. And for persistent rites and ceremonies let me quote once more the anointing of the great corner-stones of the ruined shrine of Paphian Aphrodite—the 'Queen,' as she is called shortly in inscriptions in the old Cypriote character. This observance takes place on the Feast of the Assumption of the Virgin, to whose honour, under the name Panaghiá Chrysopolitissa—the Lady of the Golden City—a church stands hard by in the precinct of the Temple. Even Moslems in Cyprus at times of stress reveal the pre-Islamic secret of their souls and bow down before the holy icon of the Virgin, painted, it is believed, by St. Luke, wafted oversea to the same Paphian shore as Venus of old, and kept by the Monastery of Kykko, to be carried in procession round fields to bring rain and bless their increase. So too do they in the remoter parts of Egypt. When I was being taken over the Church of the Convent of St. Gemiana, in the marshland of the Northern Delta, I saw a woman kneeling and muttering prayers before an icon of the Virgin. It struck me she was no Copt, and I put a question to the monk who acted as guide. He shrugged his shoulders apologetically: 'She is of the Muslamin,' he said. 'Her son is very ill. Why should she not? Who knows?'

Finally, let me return to Ephesus, whose cult with its environment I have peculiar reason to know. A phenomenon has taken place there latterly which illustrates singularly well both kinds of religious transference, the conscious and the unconscious. About fifteen years ago a Catholic priest of Smyrna who had been reading Clement Brentano's 'Life of the Virgin,' which is based on visions of the German mystic Anne Catherine Emmerich, and contains the story that Mary

accompanied St. John to Ephesus, lodged in a dwelling at some distance from the city, and there died—a belief which we know from the French traveller Tournefort to have been held locally two centuries ago—identified the holy house with a ruined building, standing above a spring in the southern hills, and dedicated by the Orthodox Church to Panaghiá Kapouli—Our Lady of the Gate. He succeeded in buying the site and much ground about it, fenced it in, found the gardens which the Virgin had tended, and the path with its stations by which she had climbed daily to Calvary on the hill-top, and when I was there was sanguine of finding also her tomb. He proclaimed his discoveries far and wide and instituted two pilgrimages which now draw thousands of Catholics every year on the Wednesday in Easter week and in the octave of the Assumption. So far we are considering a conscious revival, located by a coincidence at the great Asiatic seat of the pagan Virgin Goddess. But there is a stranger coincidence of which the good priest was not conscious. The holy house stands far from all villages or haunts of men at the head of that same glen of Ortygia where we know, from Strabo and Tacitus, stood the original shrine of the great Ephesian Mother. It stands too on obviously earlier foundations, and, as I have said, over an *Aghiasma,* as it is called, that is, a holy spring. Indeed, very possibly it occupies the actual site of the Ortygian temple. How did this coincidence come about? On this wise. When searching the Ephesian district the Smyrniote priest asked the Orthodox peasants for places sacred to the Virgin, and was directed to this in the glen as the most holy of all. It had been, in fact, a place of pilgrimages and of intercession for the sick, for rain and fertility, and for the easy delivery of women as far back as local tradition ran. This it had been because it was Ortygia, though the villagers of Kirkinji and Arvalia knew it not. In virtue of that fact the priest appropriated it, though he never suspected the identity; and thither the faithful flock twice a year, even less aware of, but none the less compelled by, the persistent sanctity of Ortygia.

Such, then, are the religious survivals which are not survivals at all in what may be called the pathological sense, not, that is to say, elements in actual religion which have survived their utility in the system; and such should not, I urge, be treated by anthropologists without explicit reference to the fact that they are as full of meaning, as vital, and as necessary in actual cult as ever they were. They offer not so much examples of the conservatism of religion—a much used phrase of slightly contemptuous implication—as of the identity of the religious sense throughout the life of particular races and within certain geographical areas, and of the necessary conditions and limitations of its expression. They claim all the respect and tenderness of treatment due to beliefs which still make part of the foundations of our social order, and cannot be impaired or cut away, like a pathological survival, without the provision of substitutes equally efficient. Even when the rudest beliefs of primitive and simple folk are dealt with, *maxima debetur pueris reverentia*; and much, be it remembered, in the content of these great classes of religious persistences is concerned with the belief of folk who are by no means simple or primitive.

There remains of course an immense body of religious persistences which are more or less rightly to be regarded as survivals in the ordinary pathological sense, beliefs, observances, and rites, that is, which have indeed survived from earlier religious systems, and have lost or are losing their meaning, because they express nothing necessary or vital to the religious sense. So far as this class includes beliefs at all, these are of the kind which are called superstitions, and I venture, despite the reluctance of some anthropologists to admit a definite distinction between religion and superstition, to maintain that there is such a distinction, and that it is just this, that superstition includes only those beliefs which are held wholly or chiefly because they have always been held; which are, in effect, results of earlier religious systems, or survivals in the narrower pathological sense of the word. Some religious beliefs may be survivals in the wider sense; all superstitious beliefs are survivals in the narrower sense.

The most numerous content of the class, however, is composed of observances and ceremonies. These may often persist as pathological survivals in connection

with beliefs of the really religious kind. The object of cult may be a survival of the necessary and vital class, as, for example, the Virgin Mother; but the particular place and manner of her worship may be conditioned by survivals of the pathologic sort. The persistence of local sanctity supplies the most obvious illustration of the latter kind of survival. For instance, while the consideration of many holy places of Christendom is due to events or traditions of Christian history itself, to connection with the Gospel story or with early preachers, teachers, or other saints, to reputed epiphanies, and so forth, a much greater number owe the fact that they are still frequented by the pious to reasons of which the pious have not the dimmest consciousness, often to features of pre-Christian Nature-worship—to rocks or springs, or even objects which may have perished long ago, like sacred trees. What Greek votary in the shrines of St. George or St. Elias could give a satisfactory account of either of those saints, demonstrate their place in the history of his Church, or say why their shrines stand in certain valleys or on certain peaks of the hills? We often know better than he; for we can say definitely that many of these saints of the Orthodox Church and of Islam, whose churches and tombs dot the Nearer East, have never died because they never lived, but are the unsubstantial shadows of old gods, clinging to the sites of shrines and groves whence their names perished long ago with the victory of the Galilean.

The particularism, which communities—village, tribal, urban, and even national—display all the world over, has had, of course, much to do with local persistence of sanctity. A small body, blessed with a private deity of its very own for uncounted centuries, who has been identified with its particular interests, and has favoured it in its multifarious local feuds, will not readily resign it for a deity of more general jurisdiction. If it accepts the Christian Virgin in place of a pagan goddess, she will be the Virgin of that particular community, unconnected with any other Virgin, and in full sympathy with the insults which Latin peasants, for example, will heap upon the Madonna of the rival village across the valley. Indeed, an instinctive distrust of and disinclination to accept an impartial god is characteristic of all imperfect humanity, and lies beneath the sectarianism which has been promptly and continuously developed within the pale of all the great universal religions—for instance, in both Islam and Christianity. The omnipresent, omniscient Deity is too far removed, too catholic, too vague. Man ever desires to focus divine attention on a smaller area, to establish for himself some preference in the eyes of his God; and, even when most anxious to bring the rest of the world into the fold, he often most jealously reserves to his own community the distinction of a Chosen People.

This great and well-known class of observances and rites, which represent true pathologic religious survivals, supplies the bulk of the matter of all the great treatises written on cult by anthropologists, such as those, for example, of Mannhardt and Bötticher on Tree-worship, as well as others to which I have already referred, and many more. With this class the anthropologist can deal freely. In the others it seems reasonable that he should move with greater reserve; and I venture to think that he will best avoid offence if he keep clearly in his own mind, and as clearly before his readers, the main distinction between the classes of religious survivals, which, quite independently of my presentation of it, is real, vital, and of momentous significance.

The following Paper was then read:—

1. *Dr. Usener's Theories concerning Sonder-Götter and 'Augenblick-Götter in his 'Götternamen.'* [1] *By* L. R. FARNELL, *M.A.*, *Litt.D.*

The Roman 'Indigitamenta,' transcribed by St. Augustine from Varro, present a long list of divinities or divine potencies that presided over the manifold and

[1] Published in full in *Anthropological Essays presented to Edward Burnett Tylor*, p. 81.

often momentary activities of man in the spheres of agricultural and domestic life. These powers are indicated by no proper personal names, but by mere appellatives that are invented to express their limited function: they appear to have a very slight degree of personality, no definite relations with concrete divinities, and no continuous life, but are merely invoked at the particular moment of a certain action. Also in the record of the Greek cults we find a species of divine beings that seem to possess a similar character, such as Ἐχετλαῖος, Εὔνοστος, Κυαμίτης, Κουροτρόφος, Καλλιγένεια, Μυίαγρος, and many others; and Dr. Usener has discovered a similar system of functional divinities designated by adjectival names in the old Lithuanian religion. A few examples have been recently gathered of cognate cult-forms among modern savage peoples. This system may be regarded as a peculiar form of animism. But Dr. Usener has coined the terms 'Sonder-Gott' and 'Augenblick-Gott' to express the character of these vague, transitory, limited divinities. Dr. Usener's theory about these gains its chief importance from two assumptions: (*a*) that these are the relics, in Greece and elsewhere, of a very primitive period when the religious imagination had not yet created the concrete personal figures such as dominate Greek polytheism, but only such shadowy half-personal forms as in the 'Indigitamenta'; (*b*) that the Greek pantheon was deeply indebted to this system, since its divinities attach to themselves and absorb many of these appellatives that once characterised independent and vaguely conceived 'numina,' and that now serve to express the complex individuality of a Zeus, Apollo, Demeter, &c.

But a critical examination of the Greek evidence, whatever may be said of his theory when applied to other religious areas, does not support his assumptions, and he does not give due weight to the other and opposing explanation of many of these Greek appellative 'numina' that, *e.g.*, Κουροτρόφος, Καλλίστη, Εὐβοσία, may be creations of the personal polytheism, mere emanations of concrete divinities like Nike of Athena, coming into being owing to the accidental detachment of an epithet from a personal god or goddess. The same epithet is often applied to many anthropomorphic divinities, and his argument that, *e.g.*, because Zeus, the Nether-God, and Dionysos are all called Μειλίχιος there must have been an aboriginal 'Sonder-Gott' Μειλίχιος existing independently whom all these absorbed, has no logical force. Again, none of these Greek appellatives of 'Sonder-Götter' proper appear to belong to the earliest stage of the language: Ζεύς is probably an earlier linguistic form than Μειλίχιος, and many of the assumed 'Sonder-Götter,' such as Ξάνθος, 'the yellow-haired one,' Καλλίστη, 'the very beautiful one,' are not functional, and if they ever existed as independent powers in the popular imagination belong obviously as much to the anthropomorphic system as Apollo and Artemis. Εὔνοστος, whose name is purely functional, and who was doubtless a very early product of a peasant-agricultural religion, distinct from the 'Olympian,' has nothing shadowy about him, but is fitted with a very anthropomorphic legend and personality. Finally, many of these appellative 'Sonder-Götter' are provably late fictions, such as Μυίαγρος and Ταράξιππος, and are merely created to assist the festivals of the higher personal gods. Doubtless many of the divinities of the Hellenes took over the epithets and names of those whom they dispossessed. But there is reason for believing that a strong personal religion, a pervading belief in concrete individual divinities, was brought with them by the earliest Hellenic tribes, and that this character also attached to much of the earlier religion that they found in their Mediterranean homes.

Joint Discussion with Section L on Anthropometrics in Schools.
See p. 704.

FRIDAY, AUGUST 2.

The following Papers were read:—

1. *Morgan's Malayan System of Relationship.*[1] *By* W. H. R. Rivers, *M.D.*

Morgan's concept of the 'consanguine family' as the earliest stage in the development of human society was founded on his belief in the primitiveness of the system of relationship now existing in Polynesia. The characteristic of this 'Malayan' system is the very wide connotation of the terms expressive of kinship, so that relatives are denoted by one term, for whom there are several terms in the more usual forms of the classificatory system of relationship.

It is unlikely that people so advanced in culture as the Polynesians should have retained the most primitive of existing methods of reckoning relationship, and there is evidence that communities elsewhere, such as the islanders of Torres Straits and the Kurnai of Australia, possess kinship systems which are in process of modification in such a way that they are coming to resemble the Malayan form, and it thus becomes highly probable that the Malayan system is a late product of change rather than the representative of a primitive stage of the human family. This conclusion is strengthened by the fact that similar approaches to the Malayan form are to be found in North American tribes which show no indication of forms of social organisation earlier than those of their neighbours.

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2. *On some new Types of Prehistoric Objects in British New Guinea.*[2] *By* C. G. Seligmann, *M.D., and* T. A. Joyce, *M.A.*

The specimens described fall into four classes, viz., objects of (1) obsidian, (2) stone of other kinds, (3) engraved shells, (4) pottery.

All are truly prehistoric, since the natives now living in the localities in which they were found cannot say who made them, and in some cases cannot even suggest for what purpose they were used. The most striking of these finds have been made by prospectors while sinking shafts, but a single piece of worked obsidian of moderate size has been picked up on the surface of the ground of Murua (Woodlarks); and on Goodenough Island a long knife-like flake, which had been recently and quite roughly lashed to the ends of two wooden spears laid side by side and tied together at intervals, was brought for trade. The most interesting obsidian implement is an axe or adze with a convex edge and a much-worked tang. The stone objects include a stone mortar weighing about 60 lb. and several heavy stone-pestles. All of these were found by prospectors in the neighbourhood of the Yoda Valley, in the northern division of the Possession. The engraved shells and the most remarkable of the pottery finds come from a site called Rainu, in Collingwood Bay. On cutting into a number of mounds for the purpose of levelling the site for a new village, fragments of pottery and human bones, with a few stone adze-blades and engraved *Conus* shells, were found. The adze-blades are of the stone until recently used in the district, but, judging from the specimens we have handled, are on the whole lighter and less effective tools. The carving on the shells consists of spirals, rectangles, and leaf-like patterns; on one shell there is a human face, which, as far as its technique is concerned, would easily pass as a piece of work from the Papuan Gulf. The pottery found on the Rainu site is superior in make and ornament to that in use at the present day in any part of British New Guinea. This part of the find includes club-heads ('pineapple' and 'emu egg' types), the necks of pottery vessels, which, from the narrowness of their mouths and the length of their necks, formed parts of vessels which must be called bottles, and a large number of fragments of pottery bowls,

[1] Published in full in *Anthropological Essays presented to Edward Burnett Tylor*, p. 309.

[2] Published in full in *Anthropological Essays presented to Edward Burnett Tylor*, p. 325.

the rims of which are broadened into a flange and are often ornamented with impressed or incised patterns. Applied ornament and practicable handles have been added in some instances, though in most specimens the handles are so degenerate as to be ornamental rather than useful.

3. *The Anthropological Field in the Anglo-Egyptian Sudan.* *By* J. W. Crowfoot.

The dervish rule, which worked havoc in the Northern Sudan, left the pagan black zone to the south almost untouched. In the Bahr-el-Ghazel region anthropologists will therefore be able to work directly upon the foundations laid by Schweinfurth and Junker; north of this, in Dar Nuba, they will find a virgin field which, though difficult to work, may yield most valuable historical results. To the east lies another district unknown until this year—the land of the Buruns.

In the Northern, or Muslim, Sudan the dervish period has completely changed the conditions. Whole tribes have been devastated, or transplanted, or mixed with black slaves or Egyptian prisoners, and written records of the past have been destroyed. The three main language groups—Nubian, Bega, and Arabic—however, remain, and scientific controversy has hitherto turned upon the origin of the people using them, the most recent conclusion being that all are African in spite of their traditions. Similar debates were raised both in the Mediæval and Roman periods, and the two facts of survival and invasion appear to be both established: the issue is one of degree how far the invaders have modified their predecessors.

If we apply Professor Petrie's views upon migrations, as set forth in his Huxley Lecture,[1] we may state the problem thus: We should expect to find three main types—a sedentary riverain type, a sedentary maritime type, and a nomad desert type, with varieties according to latitude, variants from each being classified as recent immigrants. The solution of this problem should present no more difficulties than the solution of similar problems in Europe, for the country is healthy and the people are amenable and ready to communicate their traditions and pedigrees.

As special fields in which to study the plasticity of the various types and open problems of mediæval history, which must be settled before ancient history can be approached, I suggest the following:—

(*a*) The sedentary Ababde at Daraw and in Berber.

(*b*) The families claiming Arab and Turkish origin in the district south of Halfa.

(*c*) Villages in the Shabluka cataract and on the Blue Nile claiming descent from the Anag, a mediæval people which held the Central Sudan before the last Muslim invasions.

(*d*) The tumuli in the Bega district from Suakin to the Atbara and the Nile.

When these questions have been discussed with new material, we may be able to deal with the problems raised by the exploration of Nubian temples and sites that is now beginning.

4. *Notes on the Wild Tribes of the Ulu Plus, Perak.*[2] *By* F. W. Knocker.

This paper gave preliminary anthropological results of research work amongst the aborigines inhabiting the valley of the Plus in the British protected State of Perak, in the Malay Peninsula, pending further inquiries to be carried out at a future date. After referring to the difficulties of carrying out an expedition in the remote parts of a tropical jungle, the author called attention to the problem surrounding the wild tribes of the Ulu Plus, commented on the probability of a mixed

[1] *Journal of the Royal Anthropological Institute*, xxxvi. 1906, p. 36.

[2] To be published in full in *Journal of the Royal Anthropological Institute.*

Sakai-Semang race, and quoted evidence to support the same, though on the word of the people themselves they are a pure Sakai race.

The paper then dealt with various camps separately, giving particulars of the inhabitants of each. Blowpipes and poisoned darts are not much in use, and no spears or bows and arrows were met with. Tatuing and painting of the features are practised by some, and nose-quills and necklaces of seeds and wild beasts' teeth are also worn.

Absence of religious rites and ceremonies at births, marriages, and burials seems to be general, and only very little evidence was obtained respecting superstition of any sort. The men exhibit great reluctance in introducing their womenfolk to white strangers, hence there was great difficulty in gathering much interesting data. Further up-stream this reticence was found to be fortunately absent. Clothing, though scanty, is of cloth, Malay dress being largely in evidence amongst the women nearer civilisation, but bark-cloth is worn by tribes further up-stream. Agriculture of only a very primitive nature is carried out, and the basis of food is the boiled or roasted root of the wild tapioca-plant. Houses are built of bamboo, bark and palm-leaves, but all the people are more or less nomadic. They are short in stature—as are the rest of the aborigines of the Malay Peninsula—reddish brown in colour, with black hair of a varied character. Their features are negroid, but with lips only moderately thick, and prognathism is almost entirely absent. They are friendly and hospitable towards strangers, and light-hearted in disposition. They call themselves 'Sakai' or 'Orang Darat,' the latter a Malay word meaning 'countrymen.' *Sennoi*, a heretofore supposed tribal name, they use as signifying 'person' or 'people.'

Ethnological specimens of undoubted Semang origin were collected from amongst them, and the blowpipe and poison darts, when used, are all of Semang make.

5. *A Study of the Conditions of the Maoris in* 1907. *By* Miss B. PULLEN-BURRY.

This study dealt with the population, distribution, and the Government representation of the Maoris, their transitional condition, education, religion, character, and health, and concluded with a sketch of the native land question. The census of 1906 shows an increase of over 4,000 natives from that of 1901, but the increase is only apparent. The Maori enumerations prior to 1906 are in reality valueless. The last census was taken by responsible members of lately established native village councils. The Government policy has been generous in the way of education, and with respect to the disposition of native lands, humanely conceived. Many regret that technical and industrial education is not included in the educational curriculum, and it is unfortunate that the present insecurity of land tenure has rendered the Maori indifferent and lazy. Individualising tribal communal lands in the Native Land Court is a slow and costly process, besides being accompanied with endless disputes on the part of the natives. Medical returns show that 22 per cent. of the diseases afflicting the Maori are pulmonary. Consanguineous and too early marriages conduce to racial deterioration. The village councils and 'the young Maori party' are doing much to protect, preserve, and educate the race.

6. *Notes on the Ethnology of the South-west Congo Free State.*[1] *By* E. TORDAY *and* T. A. JOYCE, *M.A.*

The inhabitants of the south-west corner of the Congo Free State, that is, the tribes living in the territory drained by the Kwango, Kwilu, and Loange and their tributaries, are the Ba-Samba, Ba-Songo, Wa-Ngongo, Ba-Bunda, Ba-Yanzi, Ba-Yaka, Ba-Pindi, Ba-Mbala, Ba-Huana, Ba-Kwese, Ba-Lua, and Ba-Djoke (also the Hollo and Tu-Kongo, with whom this paper does not deal).

[1] Published in full in *Journal of the Royal Anthropological Institute*, xxxvii. 1907, p. 133.

From a consideration of various ethnographical and historical points of evidence, the following conclusions with regard to the population of the district are reached :—

The aborigines of the Kwilu were, in all probability, the Ba-Samba, Ba-Songo, Wa-Ngongo, and possibly the Ba-Bunda, the Ba-Yaka, extending from the Kwango to the Inzia.

The Ba-Yanzi moved down from the north, occupying peacefully a country which was as yet very sparsely inhabited.

The Ba-Pindi arrived next, from the upper Kwango, occupying the country from the Inzia to the Loange, and reaching as far north as 5°·30 south.

Almost immediately the Ba-Mbala were forced up from their home on the headwaters of the Kwengo, between the Ba-Yaka and Ba-Pindi.

This movement had its origin in troubles further south, the ultimate cause being the Ba-Djoke (Kioko, Kioque, Chiboque) applying pressure to the Ba-Lua, who, in their turn, attacked the Ba-Mbala and drove them north.

At the same time a tribe of Ba-Yaka revolted from their great chief and spread eastwards to the Lukula; shortly afterwards the Ba-Huana, coming from the north—probably the region of Stanley Pool—cut through the Northern Ba-Mbala, and occupied the banks of the Kwilu. Then followed the arrival of the Ba-Kwese from the Upper Kwango: these people occupied the two shores of the Upper Kwilu, pushing in between the Ba-Mbala and Ba-Pindi. Being a people amongst whom the tribal feeling is very strong, they had probably forced their way through the sterile country occupied by the Ba-Lua. They were stopped in the north by the Ba-Bunda, Ba-Pindi, and Ba-Mbala; probably their arrival was the cause of the extension of the Ba-Pindi to the Kasai, where they were found by Wissmann. About this time a section of those Ba-Yaka already established on the Lukula appeared to have forced their way through the Ba-Mbala eastwards, crossing the Kwilu somewhere near the present site of Michakila, fighting the Ba-Mbala, Ba-Pindi, and Ba-Huana.

Further fighting resulted in the Ba-Pindi, who in this neighbourhood are very warlike, cutting off the eastern section of Ba-Yaka, which now appears as an *enclave*. The section of the country in the extreme north of the Southern Ba-Mbala territory seems to have belonged at no very remote date to the last-mentioned branch of the Ba-Yaka.

The *enclave* of Ba-Huana to the west of the main body seems to have been formed at the same time, and as a result of the same troubles. In fact, the mouth of the Kwengo appears to have been at this period the focus of deadly inter-tribal strife.

Then followed the later movements of the Ba-Kwese (related in detail in a section dealing with that people) which resulted in their abandoning the right bank of the Kwilu, succeeded by the driving back of the Ba-Djoke, who had meanwhile penetrated as far north as the sixth degree of S. latitude, and the laying waste of the strip of territory which now separates them from the Ba-Lua and Ba-Pindi.

7. *Considerations on the Origin of Totemism.* *By* G. L. Gomme, *F.S.A.*

Totemism must have arisen from conditions of human life which were universal. These conditions are supplied by the migrations by which man had spread all over the world. Migrations left the sexes differently constituted, the male being the moving element, the female the stationary element. Women in this way became more intimately associated with friendly animals, plants, and trees, and looked to them for food and protective power rather than to the males. This produced a sex-cleavage. Women influenced the totem names given to children, of which the Arunta system in Australia and the Semang system in the Malay Peninsula may be taken as instances. Natural exogamy arises from difference in totems between the fathers and the mothers. Totemism began as an artificial association of groups of people, and was not based on a kinship society.

8. *Iranian Tribes of the Ottoman Empire.* *By* MARK SYKES.

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9. *Egyptian Soul-houses and other Discoveries,* 1907.[1] *By* Professor W. M. FLINDERS PETRIE, *F.R.S.*

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10. *The Excavations at Deir-el-Bahari.* *By* Professor E. NAVILLE.

MONDAY, AUGUST 5.

The following Papers and Reports were read:—

1. *The Beginnings of Iron.* *By* Professor RIDGEWAY, *M.A., Litt.D.*

Formerly it was generally believed that iron was the gift of Africa to mankind, and, if not of Africa, most certainly of Asia. Modern research has shown that Egypt did not use iron until about 800 B.C., that the Libyans were not using it in 480 B.C., and that the Semitic peoples did not use it from a remote past, but that they borrowed it comparatively late. I urged in 1896 and in 1902 that Central Europe was the true centre of the use of iron as a *metal*, and that it was first diffused from Noricum. At Hallstatt iron was seen coming into use first to decorate bronze, then to form the edge of cutting implements; next it gradually replaced bronze weapons, and finally took new forms of its own. Everywhere else iron as a *metal* came into use *per saltum*. Man probably found it ready smelted by Nature, as the Eskimo discovered it at Regent's Bay and at Ovifak. Some still imagine that it was used very early in Egypt, because its name occurs in early documents; but this is readily explained, since hematite was known and used very early in Egypt, and the same material was used very commonly in the Ægean long before the Bronze Age. But it was treated not as a *metal* to be smelted, but as a *stone* to be ground into axes and beads. The Egyptians thus knew the mineral and had a name for it, which they continued to employ when they had learned its use as a *metal* from Europe. Others also cling to the belief that iron was worked in Central Africa from a remote time. But in Uganda, which was in touch with Egypt by means of the great lakes and the Nile, iron, as I am informed by the Rev. J. Roscoe, became first known in the reign of a king about nineteen reigns back (about five hundred or four hundred years ago). This renders it very unlikely that the metal was worked until very late in Central Africa. It is certain that the peoples beyond the Caspian, as well as those along the Indian Ocean, did not use iron till quite late; that India herself did not know it at an early date; and that Japan only got it about A.D. 700; yet some still imagine that it must have been known to the Chinese from remote antiquity. But the earliest mention of iron in Chinese literature is about 400 B.C., whilst a bronze sword belonging to Canon Greenwell has an inscription read by Professor Giles which dates it between 247 B.C. and 220 B.C. There is evidence that bronze swords were being used till A.D. 100, and that it was only then that iron swords were coming in. It is now clear that the use of iron as a *metal* is due to Central Europe.

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2. *The Sigynnæ of Herodotus: a Problem of the Early Iron Age.*[2] *By* Professor J. L. MYRES, *M.A.*

Herodotus[3] describes the Sigynnæ as a people who live mainly north of the Ister (Danube), but extend nearly to the head of the Adriatic, 'near the Veneti.' They wear 'Median dress,' *i.e.*, trousers,[4] and drive (but do not ride) small shaggy

[1] Published in *Man*, 1907.
[2] Published in full in *Anthropological Essays presented to Edward Burnett Tylor*, p. 255.
[3] v. 9.
[4] Cf. Herodotus, v. 49.

ponies. The 'Ligurians up country from Marseilles' apply the name 'Sigynnæ' to their pedlars, and the men of Cyprus to their spears. The last-named use of the word is confirmed by Aristotle,[1] and by an ancient commentator on Plato, 384, who describes this Cypriote spear as a 'throwing-spear wholly made of iron.' Such spears have been found in Cypriote sites of the Hellenic Age. Their close resemblance to the Roman legionary *pilum* cannot be due to direct imitation, for the Cypriote examples are earlier than the period when Rome reached Cyprus. On the other hand, a very similar weapon, the *gæsum* (which Hesychius describes as a 'spear like a spit, wholly of iron,' and which Athenæus states that the Romans borrowed later from the Celtiberians of Spain[2] in the first half of the second century B.C.) became known to the Romans in the latter part of the third century B.C. through the invasion of the Po valley by the Transalpine *Gæsatæ*. The home of the latter was certainly within the region within which was developed the La Tène phase of Early Iron Age culture; and both the earlier La Tène culture, and the later Hallstatt phases which preceded it, show great experimental freedom in the modelling of their spear-heads, and close approximation to the *pilum* type of weapon.

In view of the Herodotean description of 'Sigynnæ' as carrying on retail trade as far west as the *hinterland* of Marseilles, the suggestion is made that the Celtiberian prototype of the Roman *gæsum* is itself a western offshoot of the same iron culture as gave rise to the transalpine *gæsum*. Copious iron-workings have been studied by Quiquerez on the slopes of the Jura within site of La Tène and the other Swiss sites of that series; and the name of the Sigynnæ itself seems to survive in that of the *Sequani*, who still occupied the Jura and its neighbourhood in the first century B.C.

That sections of the Sigynnæ moved similarly eastward is suggested by the recurrence of their name on the lower Danube[3] and in Caucasus,[4] in both cases associated with 'Median dress' and with the same shaggy ponies. In Caucasus they inhabit a region characterised by a notable offshoot of the same early Iron Age culture as that of the Hallstatt region. An intermediate link is supplied (1) by the repetition of the name of the *'Eneti* or *Veneti* in Homeric times in N.W. Asia Minor; (2) by the survival, in N.E. Asia Minor, of a notable iron culture among the folk whom the Greeks knew as the Chalybes.

The suggestion is therefore made that Herodotus may be right in recording the same name 'Sigynnæ' as applied to the similar 'throwing-spear wholly made of iron' which characterised the Iron Age culture of Cyprus in early Hellenic times, more particularly as Cyprus preserves also a peculiar type of iron sword and a group of types of fibulæ which only find parallel in the Italo-Hallstatt region.

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3. *An Account of some Souterrains in Ulster.* *By* MRS. MARY HOBSON.

The souterrains described are for the most part situated in the two counties of Antrim and Down. The materials are rough, undressed field stones, no mortar being used. The buildings display great diversity in plan, some being merely oblong chambers and long passages; others crescent-shaped, some resembling the letter F, the same letter without the middle stroke (Γ), an inflated stocking, an uneven capital W, &c., and some are circular.

Greater variety of construction occurs in Antrim than in Down. In the former, two described were scooped out of basaltic ash; in others, rocks *in situ* were used and filled in artificially; in some, tunnelling had been done in harder rock. The entrances are small, but the tiny doorways between one chamber and another are even of more diminutive dimensions—great numbers being too small to admit the average-sized man—a person having to lie down flat in order to get through, and even then the width will not allow other than the shoulders of a woman or boy to pass through.

Tradition assigns the souterrains and the raths in which so many of them

[1] *Poetics*, 21.
[2] Athenæus, vi. 273.
[3] Apollonius Rhodius, iv. 320.
[4] Strabo, p. 520.

occur to the 'fairies,' the 'good people,' the 'Danes'—and by the latter is meant the Tuatha da Danaan, who are said to have lived in Ireland before the Celts. This race is always described as a small people. It seems impossible that any but a small people could have built and used the souterrains.

The souterrains in Co. Down run to a greater length than those of Co. Antrim; many are over 100 feet. Ardtole is 108 feet long, Rathmullan 120 feet, Slieve-na-Boley 128 feet. Heights of chambers vary from less than 3 feet to 6 feet and even 8 feet, but it is more usual to find them about 5 feet. The heights of the chambers of one at Shankbridge are as follows: first chamber, 3 feet 9 inches; second chamber, 4 feet 6 inches; the last about 3 feet, one of the 'doorways' being 17 inches square.

At Donegore and Ballymartin, in Antrim, are two caves scooped out of basalt ash. The former is 29 feet 3 inches long; the latter has a total length of 44 feet 6 inches. The stones which form the roof are very large. Their preservation in such numbers can be accounted for partly by being underground, but chiefly by the superstitious reverence with which they have always been regarded.

The structures are quite dark, of an even temperature, usually very near the surface, which accounts for many being accidentally discovered, the plough often displacing one of the covering stones. They are not oriented, yet few entrances can be successfully photographed during the middle of the day, and, in addition, they are so cunningly constructed and concealed as to be, in most cases, very difficult to find. In these counties the roofing stones are very large, while further south occurs a circular type, with overlapping courses and closed with a single stone, as in some of the tumuli, both sorts determined, no doubt, by the materials lying close to hand.

Very frequently a variety of monuments of early man are found in the vicinity—standing stones, cromleacs, kistvaens, and occasionally kitchen-middens. The only Ogam inscription found in Ulster was discovered in a souterrain at Carncomb, Connor, by the Rev. W. P. Carmody, B.A.

Detailed measurements were given, with plans, of the following: Knockdhu, Cullybackey, Tannybrack, Fort Hill, Lisnataylor Fort, Crebilly, Shankbridge, Fort of Ross, Muckamore, Donegore, Ballymartin—all in Antrim; and Ballygrainey, Backaderry, Clanmagery, Slanes, Lough Boley, in Down, &c., and one at Lucan, in Co. Dublin.

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4. *Some Objects recently found in York referable to the Viking Period.*[1] *By* G. A. Auden, *M.A., M.D.*

During the autumn of 1906 excavations for building purposes in the city of York, a few yards from the left bank of the Ouse, have revealed a number of objects which may with certainty be referred to the Viking period.

The area in question is situate at the junction of Nessgate and Coppergate, and contiguous to the site in which a large number of objects, dating from the Scandinavian occupation, were found during excavations for the Public Library and Friends' Meeting House in 1884.

Several objects are enumerated which have not been previously reported in England, and amongst these the chief interest centres in a brass chape of a sword scabbard, exhibiting an open zoömorphic interlacing design terminating in a conventionalised animal head which attached the chape to the material of the scabbard.

The zoömorphic *motif* is further illustrated by several portions of contemporaneous stonework which have been found from time to time in York. A consensus of opinion upon the objects described attributes them to the first half of the tenth century—a period which saw the Scandinavian power in York rise to its zenith.

[1] Published in full in *Ann. Rep. York. Phil. Soc.* 1906–7.

5. *Report on the Age of Stone Circles.*—See Reports, p. 368.

6. *Ninth Report on the Lake Village at Glastonbury.*—See Reports, p. 392.

7. *The Dances of British New Guinea.* *By* Dr. C. G. SELIGMANN.

8. *Religion and Custom in the South Seas.* *By* O. BAINBRIDGE.

TUESDAY, AUGUST 6.

The following Report and Papers were read:—

1. *Report on Archæological and Ethnological Researches in Crete.*
See Reports, p. 391.

2. *Excavations at Sparta in* 1907. *By* R. M. DAWKINS, *M.A.*

The work of this second season comprised (1) the further excavation of the sanctuary of Artemis Orthia, (2) the partial excavation of the sanctuary of Athena Chalkioikos, and (3) the tracing of the course of the city wall.

(1) The buildings of the Orthia site are at a temple built probably in the sixth century B.C., and lasting on until the third century A.D., although rebuilt during the Hellenistic period. Secondly, a Roman theatre, built at the end of the second or beginning of the third century A.D., in which the façade of the temple was included, occupying the position of the stage building. The Roman theatre has now been completely cleared. In the arena or orchestral area were found the remains of the altar, built at the same Roman period as the theatre itself. Beneath this altar were blocks that belonged to the altar of Hellenistic times, and in connection with them a deposit of burned refuse from sacrifices and some late Greek sherds and terra-cottas.

More than a metre below the Hellenistic level a deposit of archaic Greek objects was reached: this has now been cleared down to solid earth all over the arena and inside the temple. Above the archaic deposit was a layer of sand which had been brought from the river to raise the level when the temple was built—probably, to judge from the objects found in the sand, about the middle of the sixth century B.C. The deposit below the sand is in parts as much as a metre thick, and ranges in time from the eighth, or possibly the ninth, century to the middle of the sixth century B.C. Very near the bottom of this structure is a cobble pavement on which stands a large altar built of stones in regular courses. This altar is directly below the Hellenistic and Roman altars. The temple that existed contemporaneously with this altar has not yet been found, but there are indications that its remains are below the foundations of the Roman building The archaic altar was surrounded by a mass of burnt matter, amongst which were a quantity of fragments of burnt bones. The archaic deposit contained a great quantity of small objects and pottery. It was dug in layers, with the result that at the lowest levels no pottery except 'geometric' was found; above this 'geometric' was mixed with 'Protocorinthian' and a ware akin to 'Corinthian,' whilst at the highest levels nothing but this last kind occurred. With the pottery were found a large number of small bronzes, pins, fibulæ and animals, lead figurines, and carved ivories. These latter were either small figures of animals or men in the round, seals with devices cut in intaglio, or plaques with scenes carved on them in relief. Many, if not all, of these plaques were fastened by bronze

rivets on to the front of fibulæ. The subjects represented on them comprise male, or female, winged figures grasping birds, a warrior stabbing a gorgon, a dead man on a bier, a ship with full rigging and crew, sphinxes, a man on horseback, and others. Jewellery, engraved gems, terra-cotta figurines, some representing probably the image of the goddess, fragments of terra-cotta masks, and other objects were also found. The occurrence of amber, in view of the northern origin of the Dorians and its rarity on classical sites, is of great interest.

Thus the cult of Orthia began in the earliest times with a large altar. This altar was covered up when the temple corresponding to it was destroyed in the sixth century and a new temple built a little way off. In Hellenistic times this temple was rebuilt, but lasted on, on the same site, until the end of paganism. Under the late empire it was surrounded by a theatre, from which the rites performed in front of it could be conveniently witnessed. The altar always was in the same place, which it occupied with ever-rising level for at least 1100 years.

(2) The sanctuary of Athena Chalkioikos was found behind the theatre on the Acropolis Hill. A mass of geometric pottery shows that this sanctuary also goes back to a very early period. The building itself was much destroyed, but the finds were important. A very fine Panathenaic amphora, bronze statuettes, and a large archaic inscription were found.

(3) The work of tracing the course of the ancient city wall was continued. This has again been done largely by the discovery of tiles stamped with the information that they were public tiles used for the walls. The name of the tyrant Nabis found on some of them connects the building of the wall with him. In a few places the actual wall has been found with remains of towers.

In looking for the Agora some Hellenistic tombs were found, well built of ashlar, and containing vases and discs of stout gold-leaf chased with patterns of wreaths and flying birds.

The other members of the expedition were Messrs. G. Dickins, J. P. Droop, H. J. W. Tillyard, A. J. B. Wace, and A. Woodward. The architectural drawing was undertaken by Mr. George, and the survey work by Mr. W. Sejk.

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3. *Artemis Orthia and the Scourging Festival at Sparta.* *By* Professor R. C. Bosanquet, *M.A.*, *F.S.A.*

The excavations of the British School at Sparta have shown that the altar in the precinct of Artemis Orthia beside the Eurotas occupied the same position for more than a thousand years. This was the altar before which the Spartan youths were scourged, and from it the youth who outdid all others took the title of *Bomonikes*, or Victor at the Altar. It has always been assumed that this custom, described in detail by Roman writers, was a survival from the days of Spartan independence. Recent writers have compared it with the ordeals which, among primitive peoples, are sometimes imposed upon lads as an initiation into the privileges of manhood. But an examination of the passages relating to the custom shows that it did not take shape until after the decline of the Lacedæmonian State.

(1) In the fourth century B.C., when we have the first mention of whipping in connection with the sanctuary of Orthia, a rough game was played there in which the young Spartans had to snatch cheeses (no doubt the offerings at a festival) from the altar, while others armed with whips tried to beat them off. The element of passive endurance, so characteristic of the later ordeal, is entirely wanting.

(2) This game may have been developed out of a custom, for which there are many parallels, of the lads striking one another for luck with boughs cut from the sacred tree, the *Agnus Castus*, which grew in the river bed, and under which the image of the goddess had been discovered.

(3) In the latter part of the third and first half of the second centuries B.C. there was a complete break in Spartan traditions. Revolutions, proscriptions, and other internal disorders alternated with disastrous campaigns. Upon the restoration of the Spartan constitution under Roman protection, there was an artificial

revival of the old discipline. Sparta no longer had an army, and the training of the boys in manly virtues became an end in itself, pursued—as the inscriptions found at Sparta attest—in a curiously antiquarian spirit.

(4) From the first century B.C. onwards the scourging of the lads appears to have been a regular competitive examination, conducted under rigid rules at an annual festival, before crowds of spectators. It was called the Contest of Endurance, or simply the Scourges. The winner was the lad who bore the greatest number of blows without sound or movement, and the emulation of the boys, and even of their parents, led to protracted contests in which a competitor sometimes expired under the lash.

(5) The theatre recently excavated by the British School at Athens was built soon after A.D. 200 round about the altar and temple to accommodate the visitors who flocked to the festival. It was maintained far into the fourth century.

(6) It follows that the cruel scourgings described by Cicero, Plutarch, and many other writers were a late perversion of the old Spartan discipline grafted on a traditional recollection of the rough game of running the gauntlet mentioned by Xenophon. A false idea of the antiquity of the custom has coloured the views of Roman and recent writers on the cult of Orthia. At Sparta, as elsewhere, Artemis seems to have been worshipped, on the one hand, as the goddess of fertility, therefore as protectress of women and children; and on the other as mistress of mountains and woods and the wild life in them, and so as protectress of man, first in the chase and then also in war. The evidence of the archaic strata suggests intimate relations with Ionia, perhaps especially with Ephesus, where ivories of very similar character have been found.

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4. *Door-step Art: a Traditional Folk Art.*

(i) *The Art Relations.* *By* F. H. Newbery.

The early scribblings of children, though apparently meaningless, may be shown to be instinctive art products. As development, physical and mental, proceeds, the drawings become more purposeful and regulated, and forms are evolved that come under the heading of applied art. Illustrations of such forms occur in many of the historic styles of ornament, notably in primitive and savage art, and the whole region of 'door-step' art is filled with the designs and application of geometrical patterns and drawings created in this stage of artistic evolution. Patterns are produced in infinite variety, and are used chiefly to decorate door-steps, hearths, and the borders of rooms.

(ii) *Some Remarks on its Anthropological Bearings.* *By* T. H. Bryce, *M.D.*

The designs of the numerous examples of 'door-step' art which have been collected are traditional in character, being handed down from generation to generation. They are purely geometrical and conventional. There is no zoömorphic motive, and very rarely any attempt to represent natural vegetable forms. The art is practised entirely by women, and is entirely independent of any outside influence. The question arises whether the designs are, as Mr. Newbery interprets them, the expression of primitive art-instinct, or whether they are a survival. In any case it is very desirable that attention should be directed to the existence in this country of such primitive, untaught folk-designs, so that some adequate collection of examples may be formed before the art of the Board School kills the spontaneity of the designs.

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5. *The Origin of the Crescent as a Muhammadan Badge.* *By* Professor W. Ridgeway, *M.A.*

Primitive peoples are in the habit of wearing as an amulet the claws or tusks of the most powerful and dangerous animals. In time these claws were placed

base to base, and the crescent form resulted. The Muhammadan, therefore, adopted a pre-existing symbol, and the connection of the crescent with the moon is a later development.

6. *Note on the Ethnography of Sardinia.* *By* T. Ashby, *D.Litt., F.S.A.*

The opinions expressed by Dr. Mackenzie and myself last year in our Note on the Ethnology of Sardinia[1] have only been confirmed by a subsequent visit to the island paid by myself and Mr. J. ff. Baker-Penoyre in March last. It would seem that there is an opportunity for ethnographical research, conducted by scholars who have experience of the problems which present themselves in the Eastern Mediterranean with regard to the ethnological affinities of the earliest inhabitants, and with which members of the British School at Athens have been, in recent years, especially occupied. Nor would it be well to lose sight of the fact that the prehistoric remains of the British Isles may supply important parallels. This comparative work the British School at Rome hopes to be able to undertake in the near future.

7. *The Work of the British School at Rome during the Session* 1906–1907. *By* T. Ashby, *D.Litt., F.S.A.*

The forthcoming volume of the 'Papers of the British School at Rome' will include: A paper by Mr. S. J. A. Churchill, H.B.M.'s Consul at Palermo, on 'The Goldsmiths of Rome under the Papal Authority: their Statutes hitherto discovered, and a Bibliography'; another by Mr. A. J. B. Wace on 'Roman Historical Reliefs'; another by Mr. A H. S. Yeames on 'An Ivory Statuette in the British Museum'; another on 'The Prehistoric Civilisation of Southern Italy,' by Mr. T. E. Peet; and the first portion of a paper on 'The Via Latina,' by the Director (Dr. T. Ashby). This last forms the first part of the third section of the 'Classical Topography of the Roman Campagna,' which is in course of publication in the 'Papers' of the School. The Via Latina is one of the earliest (perhaps the very earliest) of the ancient roads radiating from Rome; and though the determination of the course taken by it presents no difficulty, the remains which have been discovered, and which still exist along its course, are of very great interest and importance.

The School has also been actively engaged in the preparation of the first part of the Catalogue of Sculpture of the Municipal Museums of Rome: in this the Assistant Director, Mr. A. M. Daniel, and Mrs. Daniel have been especially occupied. The work is under the general editorship of Mr Stuart Jones, ex-Director of the School; and it is hoped that the first part, dealing with the Capitoline Museum, may be sent to press fairly early in the year 1908.

8. *The Origin of Egyptian Civilisation.*[2] *By* Professor Edward Naville.

Who were the Egyptians? Were they a native race born in the country which they inhabited, or did they come from abroad as immigrants? Were they a mixed population, and if so, can we distinguish the various elements which formed the Egyptian nation?

The excavations made during the last twenty years by Prof. Petrie, Mr. Anélineau, Mr. de Morgan, and others have revealed to us that the primitive Egyptians presented the same characteristics as the white races which have been established from all antiquity in North Africa, and that their degree of culture had not gone beyond the Stone Age.

The knowledge we have of these Egyptian aborigines, and of their civilisation, is

[1] *Report* for 1906, p. 701.

[2] Published in full in *Journ. Royal Anthrop. Institute*, xxxvii. 1907, p. 201.

derived from the contents of the so-called prehistoric tombs, a great number of which contain deceased in the so-called embryonic posture, which is nothing but the sitting posture described by Herodotus as being customary with the African population of the Nasamonians.

The name 'prehistoric' must not be taken strictly in its chronological sense, since it is proved that the civilisation which these tombs represent lasted late in historical times. It should be replaced by the word 'native' or rather 'African,' it being well understood that 'African' does not mean 'negro.'

From the pictures of the vases we gather that the primitive Egyptians lived in huts placed on mounds. These huts were surrounded by enclosures in order to shelter the inhabitants from wild animals. At the side is a standard bearing the totem or the god of the village. The men living in those huts are hunters armed with bows and spears; their animals are those of the desert—ostriches, antelopes, gazelles. They do not seem to have been agriculturists; the absence of cattle and domestic animals is very striking. Boats with sails are seen occasionally, showing that they practised navigation and fishing.

Their physical type is decidedly not negro, though some anthropologists admit a negroid influence. They seem connected with the African natives called in the Egyptian inscriptions Jamahu and Jehennu, which originally extended further south than at the time of the Pharaohs. We have no reasons to dispute the native character of those Africans. Their civilisation, which is entirely determined by the nature of the soil and by the climate, is decidedly of African growth.

The name of the prehistoric Egyptians is the *Anu*, whom we find on the Upper Nile in Egypt, where they have left their name to *An*, Heliopolis, one of the oldest cities of the kingdom, and even in Sinai. The Anu are not foreign invaders; they are, on the contrary, the native stock which has been subdued by foreign conquerors.

The invasion took place in prehistoric times. With it appears the hieroglyphic writing. We see the invaders calling their kings 'falcons,' the symbol of the god Horus. They are the tribe of Horus coming from South Arabia, from the Asiatic land of Punt. The Egyptian sculptures show us only the African Punt, which must have been between Massowah and Somâliland. Its inhabitants are of the same race as the Egyptians. They are not Semites; they belong to the Hamitic stock.

The Arabian origin of the Egyptians is stated by several classical writers. The conquerors must have crossed the Red Sea somewhere near Massowah; they stopped some time on the Upper Nile before they settled finally below the Cataracts.

The traditions of the old Egyptians also point to their coming from the South. The victory of the tribe of Horus or the native stock was commemorated by a festival called the 'festival of striking the Anu,' which was celebrated as late as the XVIIIth Dynasty.

The movements of the first dynasties give us an idea of the civilisation of the invaders. As soon as they appear, we see domestic animals, not imported, but derived from the indigenous fauna, such as the bull, the sheep, the ass. They were domesticated by the new-comers.

On the whole, civilisation seems to have grown entirely in the last settlement of the invaders. They adopted and improved the rudimentary culture of the natives, in whom they infused their more progressive and active spirit. There is one art only which they must have brought from abroad, metallurgy, and in fact the legends speak of the blacksmiths who were the companions of Horus. They probably brought from the Upper Nile the papyrus. As for the vine, it may have come from Africa.

The first historical king was Menes, who is said to have done a great deal to civilise his subjects. He united under his rule the various tribes inhabiting the country. But he did not destroy their totems or local divinities, which became the great gods of the provinces or nomes. As conquerors and conquered belonged to the same race, and as there was no religious feud between them, they very soon amalgamated completely and formed one nation, the Egyptians.

An interesting religious object of the conquerors are the large slate palettes in

the middle of which is a round depression. This depression contained an aniconic representation of a god—what Quintus Curtius calls an 'umbilicus'—which was preserved in the oasis of Jupiter Ammon.

In conclusion, the Egyptians are a nation formed by an indigenous stock of Hamite African origin, among which settled conquerors from Arabia, who were also Hamites, coming from the same starting-point as some of the Chaldeans.

The dawn of Egyptian culture is a distinct proof of the great part played by Africa in the history of human civilisation, and supports the idea recently put forward that Ægean culture came from the South.

9. *Recent Explorations in Asia Minor and North Syria.* *By* Professor J. GARSTANG.

The expedition organised by the University of Liverpool visited Boghaz Kein and Euyuk, and obtained photographs of the sculptures, &c. Thence by Cæsarea to Cilician Gates and North Syria, discovering numerous Greek with some new Hittite and one Phrygian inscriptions. A large sculptured eagle standing on three lions on the banks of the Halys was also discovered.

WEDNESDAY, AUGUST 7.

The following Reports and Papers were read:—

1. *Interim Report on Excavations on Roman Sites in Britain.*
See Reports, p. 400.

2. *The Six Races of Mankind: their Mental Capabilities and Political and Commercial Tendencies.* *By* T. E. SMURTHWAITE.

The method of determining racial stocks in mixed races is chiefly by the cephalic index and facial contour, and these contours are only modifications of geometrical figures. The different changes in the types of facial contours are due partly to natural alterations and in part to intermarriage. The result of intermixture is shown in the shortening or lengthening of the cranial vault. The result of a careful comparison of facial contours and cephalic indices of the same persons show the merging of long types into the medium and even short-headed indices, and, on the contrary, the brachycephali gradually pass through the mesocephali into the dolichocephali. *Longheaded Types.*—The Iberian facial contour is oval, egg-shaped, or somewhat lozenge-shaped, the contour of skull oval. The Teutonic facial contour is oblong or keystone-shaped, the skull contour oblong. *Broad-headed Types.*—The Remian: facial contour conical, pear-shaped or wedge-shaped; skull contour somewhat pear-shaped. The Ligurian: facial contour pentagonal or five-pointed; skull contour squarish. The Magian: facial contour round or roundish; skull contour roundish. The Celtic: facial contour square or squarish; skull contour squarish. We find on close examination that each race shows distinct and different mental capabilities. An attempt has been made to differentiate the psychological phenomena which characterise the mental capabilities, political ideals, productive and commercial tendencies of each race.

3. *Excavations at Caerwent* 1906-1907. *By* T. ASHBY, *D.Litt.*, *F.S.A.*

The excavations of 1906 were mainly devoted to the investigation of a large house (numbered house No.VII. N) in the northern part of the city. This building had been twice reconstructed, and it was often no easy matter to determine to

which of the three periods a given wall should be assigned. In all its stages its plan was that characteristic of the larger houses at Caerwent, *i.e.*, it had rooms round all the four sides of the central courtyard. In this yard a well was discovered; samples of the mud were taken from the bottom (21 feet 6 inches below grass level) and, as before, examined for plant remains and small animal remains by Mr. A. H. Lyell, the seeds being submitted to Mr. Clement Reid, and the bones, &c., to Mr. E. T. Newton. The only novelty among the former was the sorrel (*Rumex acetosa*), the other species found having already occurred at Caerwent.

Another sample, taken from a pit at a depth of 19 feet below grass level, produced a sample of the raspberry (*Rubus Idæus*), which is another species new to Caerwent.

A very remarkable discovery was made in one of the rooms on the south side of this house. A large grey pot was found standing upright, sunk in a hole in the concrete floor of the room: it was covered by a *mortarium*, which had apparently been cemented on, and contained two smaller pear-shaped black pots and three red bowls, one with white painted decorations; also a pewter bowl with a foot, and fragments of another similar vessel, and an iron hook. In the larger of the two pear-shaped pots were some pieces of fabric; but though the earth found in the large pot was carefully examined, no clue could be obtained to the object of this strange deposit.

Work was also done on the mound on the north side of the city, but, as it is to be continued in the present year, it will be better to defer a report upon it till then.

The excavations of 1907 have led to the discovery of the Forum and Basilica of Caerwent.

They occupy the more sunny of the two central *insulæ*, that on the north of the high road. On the edge of this are remains of what may have been a monumental gateway: this leads into the open area of the Forum, on the east side of which we have found traces of *tabernæ*. On the north side of this space is the Basilica; the total extent of the building (including the rooms attached to it) is 176 feet from east to west and 104 feet from north to south.

The existence of a continuous flight of steps along the south front leads us to suppose that there were arcades all along. The aisles are about 13 feet wide and the nave 25 feet wide; the walls dividing them are 5 feet 4 inches wide. They are constructed of tiles—partly of broken flanged tiles—upon which were laid sandstone slabs which carried the columns, but which have disintegrated or been carried away for building material.

A drum of one of the columns is nearly 3 feet in diameter, and fragments of Corinthian capitals, very like those of the Basilica at Silchester, have been found.

At the east end of the south aisle is a doorway leading into the street, and at the east end of the nave is a chamber heated by a hypocaust, and approached from the nave by broad steps, probably the Curia. To the north of the Basilica is a range of rooms to which belong those described as a portion of house No. XVI. N in our last report ('Archæologia' lx. p. 128). The west termination of the Basilica lies under a garden, and has not yet been attacked. To the north of this block of buildings is a road along the south side of which we have traced the course of a line of wooden pipes—for a water-supply, no doubt. To the north of this road, in the courtyard of a house, another well, 17 feet deep, has been found, and samples of mud taken for examination.

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4. *Some Sociological Definitions.* *By* W. H. R. Rivers, *M.D.*

Anthropology has now reached a stage in its development in which it has become imperative that its technical terms should acquire definite meanings, and some kind of collective action is necessary to do what is possible towards obtaining general agreement in the use of such terms. The following are to be regarded merely as suggestions for the use of any body which may undertake the task of

defining terms on the sociological side of anthropology. I will begin with the terms for the different divisions of society.

Tribe.—A group of a simple kind occupying a circumscribed area which has a common language, common government, and common action in warfare, &c. The words 'of a simple kind' are inserted in order to distinguish the tribe from the nation.

Sept.—The social group for which there is at present the greatest diversity of nomenclature is the exogamous section of a tribe, the chief terms in use being clan, gens, sept, and totem-kin. The last term is open to the objection that there is no difference from the social point of view between a section of a tribe which takes its name from a totem, and one which has a designation of some other kind. The term *clan* is perhaps the most widely used, but is rejected by some, and it will probably be least disturbing to adopt the term *sept*, which cannot be said at present to have any definitely recognised meaning.

Phratry.—A division of a tribe larger than the sept, as in North America, including two or more septs (though it may sometimes happen that, owing to the disappearance of septs, a phratry may have only one sept).

Moiety.—When there are only two phratries, and they are exogamous, so that a member of one division must marry a member of the other, the divisions may be called *moieties*.

Class.—This term should be limited to the matrimonial classes of the Australians, or to any similar groups which may be found elsewhere.

Caste.—This is not always easy to distinguish from the tribe even in India, but it may be defined as a section of a larger community which stands in definite relations to other similar sections, which usually has an occupational basis and a definite rule of endogamy.

Family.—This term should be limited to the group consisting of parents and children. The term 'extended family' may be used for a group of persons descended from the same grandfather or grandmother or more distant progenitor (*i.e.*, where the descent can be demonstrated genealogically and is not mythical, as is often the case with the sept). Occasionally the sept and the extended family may correspond to one another.

Kin and Kinship.—These terms should be limited to the relationship set up by ties of blood which can be demonstrated genealogically.

Sib and Sibship.—The old word *sib* may be used for the relationship set up by membership of the sept.

Terms connected with Marriage and Descent.

Those suggested by Mr. Thomas in his 'Kinship Organisations and Group Marriage in Australia' may be adopted, with possibly the modification that the supplementary unions which make it necessary to distinguish between similar and dissimilar polyandry and polygyny might be separated from marriage proper, those in which a man has supplementary partners being called concubinage, while those in which a woman has supplementary partners are called cicisbeism.

Mother-right.—This might be adopted as a convenient term for a state of society in which there are two or all of the three conditions, matrilineal descent, matrilocal marriage, and matripotestal family.

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5. *Racial Types in Connaught. By* Professor R. J. Anderson, *M.D.*

It seems probable *à priori* that a sea-coast people should exhibit some ethnological varieties. A stream of immigrants from the East can scarcely be said to have ever existed in Connaught. It is true that at various times migrations from the north of the island, from Scotland and from England, west and south-west, took place; but some centuries ago emigration took place from Spain and Portugal, chiefly of merchants and their attendants, who settled down in Galway City, whilst piratical adventurers landed along the coast. Hence there is evidence of an Iberian immigration, of Norwegian local landings, and of an admixture of a

Faroe strain. It is quite likely that the explanations given by Cossar Ewart and Wendel may be regarded as applicable to the arrangements found here. Taking 200, one group, mostly from Connaught, 54 per cent. had light hair and light-blue eyes; 12 per cent. had black hair, and of these 6 per cent. had brown eyes. In a second group, entirely local and special, light hair and light-blue eyes predominate. The dark type and sallow type are also in evidence. The influence of towns is less marked in the west of Ireland than on the eastern side, and much less so than in England; so that the tendency to darkening which has been marked in town populations in England does not show in Ireland.

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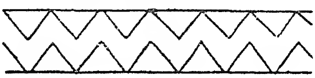
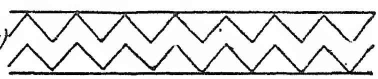
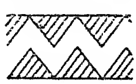
6. *A Terminology of Decorative Art.* *By* Professor J. L. Myres, *M.A.*

Decorative art, as the subject of anthropological study, needs analysis, on the technological side, in order to describe and define the precise contribution made by the artist's hand to the decoration of the object. So long as the decorative motives are recognisable attempts to represent some actual object, such as an animal or a plant, or part of one, description in general terms is easy; and, for all beyond this, graphic illustration is inevitable. But in the more abstract, and particularly for 'geometrical,' types of decoration the actual processes employed by the artist stand in a more important relation to the completed work. Artistically the effects produced by drawing on the same surface (*a*) a double series of alternate triangles and (*b*) the limiting lines of a band of continuous chevrons

(*a*)  (*b*) 

are practically indistinguishable; but technologically their origin, affinities, and potential development are quite different. For example, simple enhancement of the construction lines leads in the case of (*a*) to patterns like (*c*) and (*d*)

(*c*)  *d* 

in the case of (*b*) to patterns like (*e*) and (*f*).

(*e*)  (*f*) 

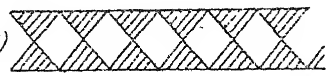
In such cases the mere graphic reproduction of the ornament is not an adequate description, still less a definition of it. On the other hand, a sufficiently precise terminology would enable a student at a distance to reconstruct from dictation a pattern which was similar technologically, and actually more valuable for purposes of comparison than a photograph of the original design.

Similar needs have led, in other sciences and arts, to the adoption of a simple conventional terminology. A botanist, for example, can convey in speech a very precise conception of the morphology of a compound leaf, and of its junction with the main stem; and heraldry has developed a terminology of the distribution of lines, subdivisions, and patterns on the surface of a shield or panel, which enables heralds to communicate at a distance almost without the use of diagrams. In pure technology the language of sewing and knitting is perhaps the most lucid and idiomatic instance.

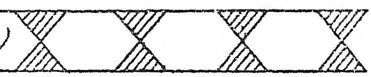
The basis of any such system, applicable to the description of abstract designs, must be strictly technological; that is, it must be essentially a description (1) of what the artist did; (2) as far as possible, of the order in which he did it, distinguishing *motif* from *enhancement* or *filling*; (3) if necessary, of the *effect* produced by the completed work, in cases where this differs from that of the artist's work while in progress. *E.g.*, in figure (*a*) we have the *motif* of 'alternate

series of recurrent triangles,' leading to a 'chevron' *effect*; in (*c*) these triangles are *enhanced* by 'hachure' or 'hatching' (a term borrowed from the engraver's art), and in (*d*) by 'cross-hatching.' In (*b*), on the other hand, *motif* and *effect* are alike 'chevron.'

In composite patterns the minor elements must be located by reference to the major element which they *enhance*, or on which they are *based*, and subsequent phrases must define their relations to each other; *e.g.*, the motive (*a*) would be described as 'between parallel lines, a convergent series of recurrent alternate triangles'; but in (*g*)

(*g*) 

the 'recurrent triangles' would be not 'alternate' but 'opposite,' and the 'effect' is that of a string of lozenges; and in (*h*)

(*h*) 

the triangles would be not 'recurrent' but 'intermittent' or 'sparse'; while the 'effect' is that of a hexagon pattern. Similarly in figures (*c*), (*g*), and (*h*) the triangles would be 'hachured' or 'hatched' *from the left*, (i.e., when viewed with their *base* downwards and their *apex* upwards), for the reason that the 'generating line' of the 'hachures' is the left-hand side of the triangle, to which they are parallels. In figure (*e*) the chevrons are 'enhanced' by 'external repetition' of their generating lines; in figure (*f*) the enhancement is 'internal.' It might eventually be possible to subsume the special term 'hachure' under the general term 'enhancement,' and to describe the triangles of (*c*), (*g*), and (*h*) as 'enhanced internally from the left.'

The elaboration of such a terminology as is here proposed should of course be gradual; it should be based upon careful comparison of terminologies actually employed in the past by expert technologists; and it should conform in its syntax to the approved usages of heraldry, systematic botany, and the like, which fortunately agree in essentials. It should take account, from the first, of foreign synonyms, and proceed—like other artificial terminologies—partly by the incorporation of brief graphic idioms from the vocabulary of the industries concerned, partly by judicious coinage of words, as in zoology, from Greek or other universal vocabularies.

Much may be done in the meantime to fix current idiom by detailed descriptive analysis of some of the commoner geometrical forms, such as the triangle (which has formed the basis of illustration here), the wavy line, the spiral, or the plait. A conspicuous instance of the confusion produced by neglect of 'terminological exactitude' is the greater part of the recent literature of basketry; and this is the less excusable, because in the allied art of weaving an ancient, idiomatic, and peculiarly accurate vocabulary exists in nearly every European language.

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7. *Report on the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*—See Reports, p. 374.

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8. *A Preliminary Report on the Progress of the University of Wales Ethnographical Survey. By* T. C. James *and* H. J. Fleure.

The survey was begun two years ago, and the measurements taken include the more important ones recommended by the Anthropometric Committee of the British Association. Any persons with any known non-Welsh ancestors are not measured. Attention has so far been concentrated on Cardiganshire, and some

700 subjects have been observed, 100 of these being women. The county has been divided into three districts, and a special study made of the central division, bounded on the east by the moors above Tregaron, and on the north by the hills just south of the Ystwyth and Wyre. The following preliminary analysis of this district will be of interest, the grouping being purely experimental:—

(*a*) Average height, 1693 mm. Average cephalic index, 76·1. Hair and eyes darker than medium brown. Face long and narrow. The group may perhaps be provisionally connected with *Homo mediterraneus.*

(*b*) Average height, 1682 mm., but with a wide range of variation. Average cephalic index, 78·2. Hair and eyes fair, reddish hair and blue eyes being a typical combination. The group may provisionally be identified with the 'Northern Race,' except that stature is low.

(*c*) Average height, 1680 mm. Cephalic index, 81. Hair medium brown and darker. Eyes grey or brown.

(*d*) Moderately tall. Fair. Cephalic indices as in (*b*), but grading into the other groups.

9. *The Cephalic Indices and the computed Stature of the Pagan Saxons in East Yorkshire. By* J. R. MORTIMER.

The data on which the paper was based were collected in various burial-grounds of the mid-wolds of Yorkshire. The series of interments may be considered as fairly representing the Anglo-Saxons of the district. Of the sixty-one skeletons examined thirty-one were dolichocephalic, with an average cephalic index of 72·3 and with a mean computed stature of 5 feet 5⅝ inches. Seven were brachycephalic, with an average index of 81·1 and a stature of 5 feet 4 inches. Twenty-three were mesaticephalic, with an index of 77 and a stature of 5 feet 3½ inches. It therefore seems clear that the long-headed people were taller than those with short heads.

10. *Report on the Exploration of the 'Red Hills' of the East Coast Salt Marshes.*—See Reports, p. 373.

11. *Interim Report on Classifying and Registering Megalithic Remains in the British Isles.*—See Reports, p. 391.

Section I.—PHYSIOLOGY.

President of the Section—A. D. Waller, M.D., LL.D., F.R.S.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

On the Action of Anæsthetics.

The duty laid upon me by the Chair which I have the honour to occupy to-day is in the first place to copy the example of my predecessors by submitting to the Section some distinct and definite contribution to the advancement of science.

And inasmuch as the subject has firmly held my attention during the last fifteen years, I am naturally led to name Anæsthesia as the title of my Presidential Address to the Section of Physiology.

With due regard paid to the fact that the audience to which the British Association addresses itself is not principally medical nor exclusively scientific, I shall deal with the subject in a manner that may, I hope, justify my opinion that it is a subject capable of being usefully considered by all educated minds.

And surely, quite apart from its value as an illustration of the method of physiological inquiry, the subject is one with which any educated man may well desire to possess some rational acquaintance, since every one of us may some day require the saving boon of anæsthesia.

Most people have some idea of what is meant by an anæsthetic, and will recognise by name at least one anæsthetic drug—chloroform. It is even probable that the first stranger whom you should meet in the street might also name ether and 'gas' as being anæsthetics. And pretty surely he would also know that the use of an anæsthetic is to abolish pain. But if you were to tell him that a plant can be anæsthetised—that seeds can be chloroformed or etherised—he might very possibly express surprise.

The popular notion of an anæsthetic, in conformity with the literal meaning of the word, is that it is something that abolishes sensibility and takes away pain. But how, then, can a plant be chloroformed? Does that mean that a plant is sensitive and can feel pain as we do? Well, probably not; nevertheless it is very certain that a plant can be anæsthetised, and when you have properly appreciated what this means I think you will admit that our notions of vital processes and of their anæsthesia by ether, or by chloroform, or by a host of other reagents have been considerably widened. For we shall then have realised that the state of a person or of an animal rendered insensitive of pain by an anæsthetic is a particular instance of the general principle that all protoplasm—vegetable as well as animal—is liable to be immobilised—put to sleep—more or less completely—temporarily or permanently—by the action of substances which we therefore designate as anæsthetics or narcotics. A volatile narcotic, like ether or chloroform, gets to the living cells of a plant by direct diffusion; in the case of ourselves and of the higher animals it gets to the living cells by the channels of respiration and of circulation. The molecule of chloroform (or of ether) is

drawn into the lungs with the inspired air, passes from the pulmonary air to the pulmonary blood, combines with its corpuscles, is thus carried first to the heart and then distributed with the blood to all parts of the body; in the capillaries the molecule of chloroform parts company from hæmoglobin, passes from the blood to the tissues and tissue fluids and enters into combination with the living cells which it immobilises more or less profoundly, temporarily or permanently. The various kinds of living cells that constitute our organs are unequally susceptible as regards the immobilising effect of this general invasion of the system by the narcotising molecules.

Of all the cells of the body, the most labile, and therefore the first immobilised, are the master cells of the body—the cells of the grey matter of the brain, that is, the seat of sensation and the organ of voluntary motion. The most stable, and therefore the last immobilised, are the executive cells of the body that constitute muscle and nerve. The order of lability from greatest to least is as follows: Brain; spinal bulb and cord; terminal nerve cells; cardiac muscle; skeletal muscle; nerve fibres. And while all living cells and tissues of the body are subject to the immobilising action of narcotic substances, their individual differences of susceptibility are such that, whereas one part of chloroform in 5,000 of blood is sufficient to immobilise cortical nerve cells, a nerve fibre requires a more than tenfold effective mass of chloroform before exhibiting any falling-off of its normal excitability.

Let us now briefly consider what happens when a patient is anæsthetised by, say, chloroform in the usual manner by inhalation of an unknown mass of vapour. The inhaled vapour, more or less diluted in air, diffuses into, and is distributed to, the entire body by the circulating blood. The lymph bath that surrounds and permeates all the tissues and cells of the body becomes a weak solution of chloroform in water, and gradually within that weak chloroform atmosphere the most labile parts fall under the immobilising effect of the anæsthetic, first the organ of conscious sensation and movement—the cortical grey matter of the brain—then the organ of unconscious reactions, the medullary grey matter of the spinal bulb and cord. So that the order in which the effects unfold themselves are (after a brief stage of excitement or mobilisation) first a suppression of sensation and voluntary movement, then a suppression of reflex and automatic movements, inclusive of the movements of respiration. Finally—and if this finally is reached the immobilisation can no longer be recovered from—the heart stops beating. The patient is dead.

From life to death by the way of anæsthesia there are three principal finger-posts dividing the journey into three stages. Of these three finger-posts two are to be carefully watched for; the third should never be sighted.

During the first stage of anæsthesia—commencing, it may be, by some amount of preliminary agitation—sensation and voluntary motion become suppressed, while reflex and automatic movements are preserved. The finger-post between this first stage and the next is quite clear: if when the conjunctiva is touched the eye winks the anæsthesia is 'light'; if the eye does not wink the anæsthesia is 'deep.'

During the second stage of anæsthesia not only *voluntary* but also *reflex* movements (of which the conjunctival reflex is the most convenient indicator) are wholly suppressed, while the *automatic* movements of respiration persist. This is the degree of anæsthesia required for any major surgical operation, and is therefore frequently spoken of as surgical anæsthesia. The finger-posts to its boundaries are: on this side the conjunctival reflex, on that side the movements of respiration.

The third and last finger-post—arrest of the heart's beat—should not be passed. Arrest of the pulse signifies an almost hopeless state. The time of grace between arrest of respiration and arrest of the pulse from which recovery is almost hopeless is very brief indeed—hardly more than a minute. The doctrine of the Edinburgh school—watch the respiration, not the pulse—is sound doctrine. Stoppage of respiration means danger; stoppage of the pulse means death.

I think this sketch, rough as it is, will be sufficient to bring before our minds

a clear picture of the process of anæsthesia and of its principal danger—cardiac syncope. I do not wish to blur it with details. I shall therefore not enter into the question of primary cardiac syncope, nor call off your attention to other symptoms such as the state of the pupil and the character of the pulse and the colour of the face. Nor shall I at present lay any stress upon the fact that chloroform can be of variable quality, and that like alcohol it may act differently upon different people.

First and foremost, if we are to secure the safe administration of a powerful poison like chloroform, we require to know how much of the drug is required for the production of the desired physiological effects, how much is dangerous, how much is necessarily fatal. Considering the fact that chloroform has now been in common use for sixty years,[1] and that the uniform experience of physiologists is to the effect that it is a dangerous drug as ordinarily used, it is astonishing that its administration should not rest upon any definite scientific basis. Occasional attempts have been made in the past—by Snow[2] first of all, by the French school of physiologists, Paul Bert,[3] Grehant,[4] Dubois,[5] and others, more recently by committees of medical societies and of the British Medical Association[6]—to determine what may be designated as the physiological arithmetic of chloroform; but partly by reason of the difficulty in the way of measuring percentages of chloroform in the air and in the blood, partly by reason of the facility with which chloroform can be administered without any reference to percentages, the results obtained produced very little impression upon clinical practice, and deaths that could not have occurred if the principles laid down by Snow and by Bert had been properly appreciated and acted upon, were and still are regarded by the medical profession and by the public as the normal incidents of medical practice, and attributed to any but their true cause—an overdose of chloroform.

I shall not venture to guess at the number of avoidable deaths that have taken place from this cause, but I place before you a diagram constructed from the annual returns of Somerset House and giving the number of deaths officially classified under the heading 'Anæsthetics' during the last fifty years. I do not wish to use the diagram in an alarmist sense, so I hasten to call your attention to the fact that the numbers are not percentages, but absolute figures which may in your opinion be sufficiently accounted for by the fact that the absolute number of cases has augmented in which anæsthetics have been employed, and that official returns of fatal cases may have become more complete.

Indeed, I do not myself base my judgment of the matter so much upon statistics, which are notoriously apt to be imperfect and misleading, as upon the common experience of most members of the medical profession and of many persons outside that profession; I have rarely met a well-informed person who was not personally acquainted with at least one accidental death by chloroform. Nevertheless I have presented to you the above statistical diagram because I consider that with due reservation this outcome of unprejudiced observation gives a by no means exaggerated picture of an actual fact, and because I believe it is an avoidable fact and will be diminished in future years by the wider knowledge of the physiology of anæsthesia.

I hope I shall not tax your attention too severely if I ask you to follow me through a short arithmetical argument in order to convince you that accidental deaths by chloroform must of necessity be expected to occur in the ordinary way of administration if the administrator is not fully alive to the physical and physiological properties of chloroform, and to outline in your minds a definite picture of some very simple and important measurements.

By ordinary methods of administration the percentage of chloroform vapour in the mixture of chloroform and air inhaled may be anything between 1 and 10 per cent.; let us say that it is 4 per cent.—*i.e.*, that an inhalation of, say,

[1] The first major operation under chloroform was performed by Sir James Simpson on January 19, 1847.

[2] Snow *On Chloroform and other Anæsthetics*, 1858. [3] Paul Bert.

[4] Grehant. [5] R. Dubois. [6] B.M.A.

500 c.c. carries 20 c.c. of chloroform vapour into the lungs. Of this 20 c.c. it is no exaggerated estimate to take one-half, or 10 c.c., as absorbed by the pulmonary blood, the other half being expelled in the expired air. If the subject breathes twenty times per minute 500 c.c. at each inspiration, his blood absorbs 200 c.c. of chloroform vapour in one minute—*i.e.*, one gramme of fluid chloroform. He may, of course, absorb less than one gramme per minute; but he may also absorb more. Snow estimated that 17 minims of chloroform in the blood (*i.e.*, about one gramme) was sufficient to produce anæsthesia, while double the amount was fatal.

Grehant found that after death by chloroform the blood contained half a gramme of chloroform per litre of blood—*i.e.*, five litres of blood, which is the normal amount in an average man, would contain two and a half grammes. Buckmaster and Gardner find from numerous experiments results that may be summarised as follows:—

Quantity of chloroform (in grammes) contained in 100 grammes of blood:—

	Min.	Mean.	Max.
Taken during deep anæsthesia . .	0·020	0·030	0·040
Taken after death by anæsthesia . .	0·040	0·050	0·060

These results signify in five litres of blood between one and two grammes as the anæsthetic amount, between two and three grammes as the lethal amount.

Consider, then, what might happen if a patient were to absorb chloroform at anything like the rate of one gramme per minute, and what might happen if by mischance he should absorb two or three grammes in a fraction of a minute. This is a mischance that can occur in the ordinary method of inducing anæsthesia: a few deep gasps by a struggling patient, a few moments' inattention on the part of an administrator, and the blood almost at once be fatally overloaded with chloroform.

In the early days of chloroform anæsthesia it used to be considered admissible to administer chloroform vapour of 4 and 5 per cent. strength in air; but at that time the means of estimating percentage were very imperfect, and the figures quoted were little better than guesswork.

The dictum of the Edinburgh school was 'plenty of chloroform with plenty of air by continuous administration.'

Some ten years ago, at a meeting of the Society of Anæsthetists,[1] I pleaded for the continuous administration of chloroform vapour at a strength (in air) of not below 1 per cent. and not above 2 per cent., which amounted to a translation into figures of the Edinburgh dictum, with justification of the figures by quantitative observation. Perhaps I may briefly explain the method[2] by which the percentages of chloroform and air are obtained:—

	Grammes
A litre, or 1,000 c.c., of chloroform vapour weighs . .	5·333
A litre, or 1,000 c.c., of air weighs	1·288
The litre weight difference is therefore	4·045

The weight difference of 1 c.c. is approximately 4 milligrammes.

So that a 100 c.c. flask in which 1, 2, 3, &c., c.c. of air are replaced by 1, 2, 3, &c., c.c. of chloroform vapour is 4, 8, 12, &c., milligrammes heavier than the same flask filled with air.

So that added weights of 4, 8, 12, &c., milligrammes indicate 1, 2, 3, &c., per cent. of chloroform vapour present.

Thus, by simply counterpoising a 100 c.c. flask (or, preferably, a 250 c.c. bulb, as to give weight increments of 10, 20, 30, &c., milligrammes as indications of 1, 2, 3, &c., per cent.) filled with air against a similar bulb filled with chloroform mixture, the percentage of the mixture is read directly by the number of centigrammes required to counterpoise. For instance, a bulb full of mixture being,

[1] Waller, *British Medical Journal*, April 23, 1898.
[2] Waller and Geets, *ibid.*, June 20, 1903.

say, 18 milligrammes heavier than when it is full of air, the chloroform vapour percentage is known to be 1·8 per cent.

Evidently, with a ready means of estimating percentage, one is entitled to talk about the percentages that one considers from experiment to be necessary and sufficient and excessive.

My argument up to this point comprises one or two tacit assumptions that ought to be briefly dealt with, or, at any rate, mentioned.

In the first place, I have assumed that the great majority of accidents by anæsthetics are caused by chloroform.

This is accounted for by the fact that chloroform is the most powerful, the most convenient, and the most extensively used of all anæsthetic vapours. I hasten to add that, in my opinion, this fact is an argument not so much for the substitution of other less dangerous anæsthetics as for the more careful administration of chloroform itself.

In the second place, I have assumed that chloroform is a remarkably uniform and certain reagent, producing its physiological effects in strict conformity with the quantity of vapour administered, and by no means irregular in its action by reason of irregularities or impurities of manufacture. Pure chloroform is more powerful than impure chloroform.

I do not dwell upon these two points now; nevertheless I should like to say that these are not gratuitous assumptions, but, more properly speaking, results of observation and experiment, of which I can offer some evidence. I have tested purified chloroform against the concentrated residue of its impurities, and have found the former to be far more powerful than the latter. And I have compared with each other chloroform or trichlormethane, $CHCl_3$, dichlormethane, CH_2Cl_2, monochlormethane, CH_3Cl, tetrachlormethane, CCl_4, as well as many anæsthetics of the ether group, Et_2O, EtCl, EtBr, EtI, and several anæsthetics belonging to the series of chloroethanes, members of which have at various times been recommended as substitutes for chloroform—*e.g.*, ethylene chloride or 'Dutch liquid,' CH_2Cl-CH_2Cl, and ethyledene chloride, CH_3-CHCl_2. The conclusion I have drawn from this study is that of all these more or less powerful anæsthetics chloroform is the most powerful, the most certain, the most convenient, and the most trustworthy.

But I would repeat the statement that the safe administration of chloroform consists in its continuous administration at a strength of between 1 and 2 per cent. And if anyone now objects that it may be safe to go up to 3 per cent., or sufficient to go down to ½ per cent., I am content to accept the objection as being possibly well founded, because it carries with it the all-important admission that the question of safe anæsthesia is in first instance a question of quantity, and in second instance a question of idiosyncrasy and of clinical conditions.

Admitting, then, that the primary condition of the safe administration of chloroform consists in the continuous administration of an atmosphere in which chloroform vapour is between the limits of 1 and 2 per cent., the question is how best to secure this essential condition. It can be secured by many methods. Given the requisite care, skill, and experience on the part of the administrator, anæsthesia may be properly carried out by any method, empirically or otherwise. But some methods demand more skill and care than other methods, and the task of the anæsthetist may be lightened (or it may be aggravated) by various mechanical appliances. A folded towel drenched with chloroform may be safely used by an anæsthetist whom previous experience has rendered fully alive to the extreme danger of two or three deep inspirations of a concentrated vapour, and whose attention is never distracted from the paramount necessity of 'plenty of air' with the 'plenty of chloroform.' On the other hand, a person unmindful of the physiological elements of chloroformisation is a dangerous administrator if he is content with the empirical use of any apparatus, however faithfully he may carry out the instructions of his instrument maker.

Methods and apparatus are legion, and it would be futile or invidious on my part to attempt to describe or criticise in detail any one method or apparatus. But I may usefully invite your consideration of certain principles and ask you to

recognise that for their trial by experiment the chief necessity is a simple method, such as I have just described, enabling us to test percentages quickly. Thus, by the use of this method, Mr. Symes[1] has determined what are the usual percentages of chloroform vapour offered to inspiration by an ordinary Skinner's mask, and found them to range between the desirable limits of 1 and 2 per cent., with occasional fluctuations up to about 3 or 4 per cent.

All apparatus designed for the delivery of chloroform vapour of definite and controllable percentage is based upon one or other of two principles. On the first or vacuum system, of which the best known examples are the apparatus of Snow and that of Harcourt, the patient inspires air through a vessel containing liquid chloroform by a broad inlet tube and a closely fitting face-piece.

On the second or plenum system, of which the examples best known to me are the apparatus of Dubois and that to which I have given the name of the 'wick vaporiser,'[2] the patient inspires from a freely open face-piece in which an excess of chloroform and air at required percentage is maintained by a pump.

In my opinion, if apparatus is to be adopted, the plenum is preferable to the vacuum principle: for in the latter case it is more difficult to secure uniformity of administration, which requires a perfect fit of the face-piece, stillness of the chloroform over which the inspired current of air is drawn, and which causes of necessity a considerable added resistance to inspiration. By the plenum system there is a more uniform percentage of supply, and the patient breathes freely from an open loosely fitting face-piece, the cavity of which is kept filled to overflowing by an excess of mixture of controllable strength.

But, whichever of these two systems be followed, the choice is obviously one that can only be determined by experience, both clinical and of the laboratory. Equally obviously the so-called accurate percentages afforded by any method can only be approximately accurate under the sometimes difficult conditions of practical administration, and it is therefore of principal importance to ascertain by a simple and ready method of estimating percentages such as I have described above what is the degree of accuracy, or, if you prefer to say so, the range of inaccuracy to which any method or apparatus is subject under the ordinary conditions of its application

You may indeed sometimes hear it said that the percentage can be judged of by the sense of smell, which therefore affords the readiest means of estimating the strength of a mixture, to which I should like to add yes certainly, provided the observer by previous experience of known percentages has formed some standard of comparison on which his opinion is based.

I have finished what I set myself to say to-day concerning the physiological problems involved in the question of safe anæsthesia by chloroform.

But I have reserved for my conclusion certain considerations by which it is customary to introduce the particular subject under review. May I briefly trespass further on your attention to say something about the conditions under which physiological inquiry is pursued in London?

Physiology, in the technical and restricted sense commonly received in this country, has become so closely associated in the public mind with vivisection, and, as dealt with in the medical curriculum, is so narrowly reduced to what is strictly necessary and practicable, that its real scope and value as a general science have been altogether lost sight of.

I do not propose on the present occasion to deal with the question of vivisection either on its ethical or on its utilitarian aspect. All I wish to do is to bring distinctly before your minds two considerations that may, I hope, contribute to a broader and truer conception of the place of physiology among the sciences, though they assuredly will not justify the claim of Dubois-Reymond that physiology is the queen of the sciences.

The first of these two considerations is that the province of vivisection, essential as it is, is a very narrow and restricted province indeed in the domain of

[1] Symes, *Lancet*, July 9, 1904.
[2] Waller, *Proc. Physiol. Soc.*, August 19, 1904.

physiology. In the ordinary routine of the physiological laboratory experiments involving vivisection are infinitely less numerous and infinitely less exacting than experiments that involve no vivisection. Vivisection is, in fact, an infinitesimal fraction of experimental physiology, whereas in the minds of many who should know better experimental physiology always means vivisection: the two terms are taken as synonymous, and an odium that should not have been attached either to physiology or to vivisection has been directed through vivisection upon the whole of physiology. Yet do not mistake my meaning. I do not for one moment surrender the claim that upon ethical and utilitarian grounds vivisection is lawful; I deprecate the perverted picture of vivisection that is presented to public opinion by sensational agitators and the perverted notion of physiology that is one of the evil results of the anti-vivisection crusade. But I do not desire to dwell on the vivisection question; I do not consider that it can be usefully considered by the general public without an intimate knowledge of the subject, itself possible only to the specialist. An ordinary normal person who should say he approved of vivisection would be, in my opinion, even more objectionable than an ordinary normal person who should express a detestation of vivisection, for the bare idea of vivisection is repugnant to every humane person. To bring dispassionate argument against such natural repugnance seems to me hardly less mischievous than to fan repugnance into hatred by passionate appeals to the imagination. The surgeon to whom an ignorant crowd should impute cruelty would fail to serve the cause of humanity by the technical descriptions to them of the operations he is required to perform.

There are two great principles involved in the welfare of any applied science—in the welfare indeed of any living thing—the conservative principle and the progressive principle.

Any organised living mass—let it be an animal or an organised body of men—by virtue of the conservative principle of heredity, of repetition of like by like, of imitation of action that has proved to be successful, works more economically than it could have done if each individual mass had perforce to work out its own salvation, evolve for itself its own suitability to and temporary mastership of surrounding circumstances.

But the child that can only imitate and repeat the actions of its ancestors brings no positive addition to the excellence of the race whose upward progress requires to be fed by the costly process of initiative efforts, by the sports of talent and of genius, by the cumulative effect of innumerable hits among innumerable misses of innumerable multitudes of individuals.

Transfer this thought to education—to medical education in particular. An educated person—a competent physician or surgeon—must in the first place learn at the feet of his masters, believe and learn what he is told, imitate what he sees done by his instructors, be the apprentice and follower of the experienced craftsman who shows him tried and approved ways of working.

But the apprentice who is to contribute to the commonwealth of knowledge and power has to be something more than the faithful imitator of his teacher; he must initiate, and he must make a hit among, it may be, his many misses. He will then have contributed to the advancement of knowledge and power.

In all provinces of human activity we may distinguish the result of our two complementary principles—imitation, the conservative principle; initiation, the progressive principle. But while in all provinces the conservative factor, being, so to speak, the means of wholesale economy, bulks the larger, the progressive factor, as the means of retail economy, is relatively insignificant.

Between the two extremes—imitation on the one hand, initiation on the other—there is room for numberless variations; and, by reason of the vastness of area of even the minutest province of human activity, the aim of education even the most technical is perforce more and more directed to teach the pupil to use his own mind in presence of the task set him rather than to copy minutely and to reproduce perfectly the model facts shown or described to him by the master.

But in every province, and in particular in that of education, the power of imitation is easier to exert and easier to develop than the power of initiation

which is a rare and costly ingredient, since at any given juncture the odds must be heavily in favour of the success of the time-honoured fact or method as compared with its yet untried competitor.

There are of necessity many misses and few hits among the novelties that come to trial.

The genius of our nation is admittedly a practical genius that looks upon the conservative way as the better way, and makes its changes by as small steps as can be from precedent to precedent. This is the safe and easy way, the way of nature; and to this predominance of fact copied over fancy realised may fairly be ascribed our own prolonged constitutional prosperity. We have found by long experience that it is very long odds indeed against any dark horse without a good pedigree of precedents, so we prefer to back the field; old methods are the safe thing and the good thing.

But one may have too much of a good thing, and in education I think we have had too much of the old methods, in which the keynote is imitation and examination of copy, and too little of that expensive and dangerous ingredient—so dangerous that to some authorities it appears in the light of a poison—initiative and originality of thought. I admit all the danger; I grant to the old authorities that there is a good deal of trash current under the label of original research. But I do not think we can have wheat without chaff, and I am convinced that the adherents of original research, as against the *clientèle* of the examiner and of the crammer, bring to the educational commonwealth the scanty and much needed ingredient of initiative. We want education still further urged in the direction of teaching the pupil to use his own mind upon unseen translation of new facts into effective conduct, and one of the best ways of obtaining that the teacher shall guide his pupils to use their own minds is that he should himself use his own mind, and not suffer himself to drop into the jog-trot of routine. We want our teachers to be learned men, but we also want them to continue to be learning men; and that is why, in spite of its defects, I want to urge that greater encouragement be given to original research.

I hope I shall not have taxed your patience too far if I bring these considerations to their natural conclusion by telling you as briefly as may be of an effort that is now being made in the University of London to strengthen and organise that spirit of initiative which is, I am convinced, of capital importance in all teaching, the most elementary no less than the most advanced. We have formed ourselves into a school of physiology, including every teacher of physiology in London, each of whom undertakes to give at the headquarters of the University lectures upon those portions of the science with which his own previous study has rendered him specially conversant. The teaching offered is of an advanced character, and is addressed more especially to post-graduate and to Honours students; and, in pursuance of the principle that such teaching is the immediate consequence of learning, the University has provided a research laboratory in which teachers and other post-graduate students find the necessary facilities for work. We believe that the experience of the last five years has sufficiently proved that a 'college of learning' thus constituted renders valuable assistance to the teachers and students of the schools of London, and that it is helping to draw to a focus resources and efforts that are at present scattered and wasted among the several schools. I cannot do better in this connection than quote the words of the Chancellor of the University (Lord Rosebery): 'We hope to make this laboratory the central spot for medical research in London . . . an institute of studies ancillary to medicine, which may develop and complete the work of the University in that direction.' And I think that you will agree with me that any movement that contributes to the good health of the University of London contributes to the good health of every university in the Empire, and of every school whose teachers are animated by the university spirit—the love of learning for its own sake as well as for the sake of the mental and material power that is required of us.

The following Papers and Report were then read:—

1. *Cancer Investigation: with special reference to the Gastric Secretion of Hydrochloric Acid.* *By* S. MONCKTON COPEMAN, *F.R.S.*

Professor B. Moore and his colleagues, Messrs. Alexander, Kelly, and Roaf, have shown that deficiency of HCl in the gastric secretion in cancer is not, as previously believed, confined to cases of carcinoma of the stomach itself, but that it can be demonstrated equally in patients suffering from cancer, wherever situated in the body. It appeared that the recent development of experimental cancer research, involving the transplantation of Jensen's and other similar tumours from one to another of a series of mice, would be likely to afford a means of accurate control of the results obtained in man.

Material for the purpose has been supplied from the laboratories of the Imperial Cancer Research Fund, and the amount of physiologically active hydrochloric acid in the stomach contents of nearly 1,000 mice, either normal (for purposes of control) or suffering from inoculated cancer, has been estimated by means of the method devised by Dr. Willcox. Taking into consideration the whole series of experiments, there has been found, on the average, a decided INCREASE of physiologically active HCl, amounting in some instances to as much as 50 per cent. The meaning of this divergence from results obtained in cases of human cancer is at present under investigation.

As the result of the work of various observers on the demonstration of HCl in the gastric secretion, dependent, as it apparently is, on an increased alkalinity of the blood, it would seem that cancer must be regarded as the local manifestation of perverted body metabolism, and in this connection it is of interest to note that there is already some evidence that *gout* (in which the alkaline reaction of the blood is diminished) and *cancer* are mutually antagonistic, inquiries, statistical and otherwise, having up to the present failed to obtain evidence of occurrence of these two diseases in the same patient.

2. *The Investigation of the Effects of Climate by means of Laboratory Experiments.* *By* Professor ZUNTZ.

The author gave a short report of investigations begun and partly finished on the effect of tropical climate on human metabolism. The principal questions to be answered are the effect of the climate on the work of the digestive apparatus during rest and during exercise. Dr. Schilling and Dr. Jaffé are doing those experiments at Togoland; the chemical analysis is performed at the laboratory at Berlin. Moreover Zuntz considers it a most important part of the research to study the secretion of the skin, which work he has begun already in the Alpine climate, and together with von Schrötter in balloon ascents.

Secondly, Professor Zuntz gave a description of a respiratory chamber of large size, containing a treadmill adapted to different kinds of muscular work. This chamber is ventilated by the method of Regnault and Reiset, and gives the possibility of producing any temperatures and any degree of moisture required.

3. *The Study of Sea Climate.* *By* Dr. FRANZ MÜLLER.

4. *Report on the Effect of Climate upon Health and Disease.*
See Reports, p. 403.

FRIDAY, AUGUST 2.

The following Papers and Report were read:—

1. *The Nervous Impulse. By* Professor J. S. MACDONALD, *B.A.*

The nervous impulse travels at a rate of 30 metres per second, that is to say, at about the rate of an express train. The chemical and physical changes characteristic of its passage were therefore difficult to examine. The fact, however, that two stationary conditions, namely, the condition of injury and the condition found at the kathode through which a polarising current was led out of the nerve, presented in all probability all the essential features of the same change, offered an indirect opportunity for the study of this process. In both of these conditions the same leading features could be identified, the colloid materials of the fibre were precipitated and a new material made its appearance, which in greater part at least could be identified by appropriate tests as potassium chloride.

In view of these facts it was suggested that the nervous impulse was a physical process in which a change in the size of colloid particles led to the liberation and subsequent free movement of salt solutions condensed upon their surface. This free movement of new salt solutions was capable of effecting all the phenomena characteristic of the nervous impulse.

2. *Spinal Reflexes. By* Professor C. S. SHERRINGTON, *F.R.S.*

Records of spinal reflexes were shown illustrating the grading of intensity of the reflex movements in accordance with grading of intensity of the electrical stimulus used. This was demonstrated to be the case when the reflex contraction of a single muscle among those responding was taken for examination, as well as when the movement of the whole limb was used for recording. It was also the case when the stimulus used was a single break shock applied either to the skin or to an exposed afferent nerve. Examples of the staircase effect were also shown from the action of reflex centres.

It was also reported that the change produced by strychnine in the inhibition part of the flexion reflex can be traced to occur through the early supervention of what is usually an after rebound of excitation. The change from inhibition to excitation produced by strychnine is easily temporarily reconverted back to inhibition by even a small dose of chloroform.

3. *Metabolism of* Arum spadices : *Enzyme Action and Electrical Response. By* Miss H. B. KEMP *and* Miss C. B. SANDERS.

In a paper to the Botanical Section last summer we showed that the rise of temperature in the *Arum spadices* on the unfurling of the spathe is accompanied by a marked rise in CO_2 production and O_2 absorption, which follows very closely the temperature curve.

The disappearance of starch in the tissue led us to some preliminary chemical tests which made it appear probable that there was a concurrent phase of extreme enzyme activity, and the putrefactive smell pointed to the presence of proteases. By the following tests (amongst others) one of us has ascertained the presence of these in *A. maculatum, italicum, elongatum, crinitum, Sauromatum guttatum,* and *Dracunculus vulgaris.*

Extracted from the crushed spadix, twenty-four hours, and filtered (covered with toluol solution): The filtrate with 5 per cent. starch solution gives disappearance of starch in forty-eight hours. Boiled controls negative.

The filtrate with $\frac{1}{5}$ vol. Witte's peptone solution in neutral HCl 0·025 per cent.;

with acetic 0·2 per cent. gives in all cases tryptophane reaction in forty-eight hours. Boiled controls negative.

Extract with fibrin (boiled in urea) in natural medium (faint acidity) $NaCO_3$ 1 per cent.; acetic 2 per cent. All give tryptophane in twenty-four hours. Boiled controls negative.

Extract with ground barley, shaking twenty-four hours. Kjehldahl estimation of soluble nitrates shows 7·05 per cent. increase in unboiled over boiled. (Dr. Horace Brown's method—we are very much indebted for help in this.)

Crushed spadix auto digest: under toluol, with NaCl, 0·2 per cent.; with salicylic acid, 2 per cent. Tryptophane is present after forty-eight hours, and has totally disappeared in fourteen days. Boiled controls never show any trace.

Crushed ovules and ovule region give no tryptophane.

Oxydases were tested for in *Dracunculus*, *S. guttatum*, and *A. crinitum* with H_2O_2 and guaiaconic acid. They are present in the spadix, but hardly traceable in the filtrate.

The disappearance of tryptophane above noted under aseptic conditions seems of peculiar interest as a result of enzyme activity. Material has been wanting for determining whether it is due to further cleavage of the molecule or to oxidation in the presence of strong oxydases.

The sad failure of our growers (to whom we are nevertheless much indebted) to give an adequate supply of material has up to now prevented us from tracing the point in floral development at which each enzyme is liberated, or from obtaining any quantitative analyses apart from those of gaseous interchange.

The electrical responses under these very active conditions seemed likely to be of value. In *Sauromatum* the very elongated spadix frequently shows an unequal state of activity (as indicated by the temperature) in different regions. The responses were found to bear a definite relation to this hotter region—namely, to run from inactive to active spot within the tissue. The normal current (*i.e.*, prior to stimulation) was of opposite direction. The responses over short distances were of opposite direction to the stimulation, extra-polar currents away from the stimulated region at either kathode or anode.

The values varied enormously.

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4. *The Play of Forces in the Normally Dividing Cell.* *By* Professor Marcus Hartog, *D.Sc.*

The processes, dynamic and other, of the normally dividing cell may be analysed as follows:—

(1) Such as are known in the inorganic world: (*a*) osmosis and turgor, found in the enlargement of the spindle; (*b*) traction and tension of the viscid threads of the spindle; (*c*) fluid resistance deforming the disceding chromosomes; (*d*) solution and desolution; (*e*) surface tension.

(2) Such as are known to occur elsewhere in living plasma, but which have not been adequately referred to physico-chemical phenomena: (*a*) growth of centrosomes of chromatic substance and of achromatic fibres; (*b*) protoplasmic movements, and especially that which is expressed in the elongation of the spindle; (*c*) the transverse division of the elongated viscid bodies, with increase of their surface, occurring in the chromatin granules at right angles to the threads in which they lie, and in the final division of the cell; (*d*) the fusion and apparent loss of identity of the daughter-chromosomes, and in the reconstitution of the daughter-nuclei.

(3) 'Mitokinetism,' a force analogous to electrostatic force, manifested in the karyokinetic figure, in the splitting of the chromosomes, and in the discession of their daughter-segments.

(4) Such as find no clear equivalents elsewhere: the resolution of the nuclear network into a definite number of chromosomes, the orderly sequence of events,

the different phenomena leading up from different beginnings, by different routes to the same end.

These theses are shown in a consecutive review of the changes in a normally dividing cell.

In the complex process taken as a whole we can find no promise of an explanation by the exclusive play of physical and chemical processes known outside the living organism. Still more is the history incompatible with a reference to any one single dominating force, such as osmosis (Leduc), or changes in electrostatic potential due to transformations of colloids (Ralph R. Lillie, G. Mann, Angel Gallardo).

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5. *Report on the 'Metabolic Balance Sheet' of the Individual Tissues.*
See Reports, p. 401.

MONDAY, AUGUST 5.

Discussion on the Physiological and Therapeutical Uses of Alcohol.[1]

Professor Cushny said that, though the exaggerations of anti-alcoholists had produced a reaction in the public mind, the uses of alcohol in medicine in the past had been entirely erroneous. He proposed to confine his observations to the action of alcohol on nutrition, on the brain, and on the circulation. There was an idea that alcohol both improved digestion and acted as a food itself; but a large number of investigations had not been able to confirm the idea of the improvement of the digestive processes as a whole, though sometimes they acted more quickly in individual cases. Alcohol might sometimes increase the taste for food, which was no doubt of great importance, and so improve gastric secretion; yet, in general, there was no greater amount of food absorbed in the day whether alcohol was or was not used, because the increased gastric juice was devoid of or poor in ferments, and could scarcely promote the preparation of food for absorption. When moderation was departed from, the whole of the digestive processes were disorganised. While the usefulness of alcohol in treating some digestive disorders might still be uncontroverted, for its effects were very complex, Binz's dictum that the healthy stomach needed no stomachic, and therefore no alcohol, must be the standpoint of the physician to-day. But it might be argued that the present artificial conditions of life necessitated measures unnecessary in a more healthful environment. Did not the jaded appetite demand exceptional measures, and might not wine be used to render food palatable and promote gastric secretion and digestion, just as other condiments, like mustard, are employed? The answer was that the objection to alcohol did not arise wholly from its effect on digestion, but from the tendency towards the habit being formed and from the specific action of alcohol on the brain. In respect to the food-value of alcohol, experiments over many years had shown that over 95 per cent. ingested underwent combustion in the tissues and was utilised by them as a source of energy for muscular strength and body-heat. Alcohol was therein strictly comparable to sugar, which was also an alcohol, though of a more complex nature. And, in fact, the more closely the metabolism under alcohol was examined, the more clearly was it seen to conform to that under an equivalent amount of carbohydrate; and it seemed to him that the protagonists in the fight against alcohol could only harm their cause by still refusing to accept these results, for the recognition that alcohol resembled sugars and fats in its fate in the tissues by no means implied that it was a suitable food in disease or in health. The same was true of vinegar, or even of morphine, under

[1] Reprinted from *The Times*, August 6, 1907.

certain conditions. The question was, Could alcohol be taken without toxic effects on the tissues in general, quite apart from those on the brain and more specialised organs? On this point experiment had shown that alcohol appeared to behave like other nitrogen-free foods when substituted for other forms of food in persons not accustomed to its use, in that it sometimes failed to act as an equivalent for some days, during which the deficiency had to be made up by combustion of other available sources of energy, but that this effect was not proved to be toxic in its nature. But another series of investigations had shown that alcohol left the tissues in an impaired state, and that its abuse lessened the resistance to invasion by pathogenic organisms; the records of pneumonia in our hospitals and of cholera in the East indicated this beyond doubt. But they failed to show that it was beyond question that the habitual use of alcohol in small quantities or its therapeutic use had this effect, and the whole interest of the question at present lay in the dietetic use of alcohol as contrasted with the drunkard's abuse of it. The effects of alcohol on the central nervous system differed very considerably in different individuals. In the lower animals they were marked by depression; the symptoms were exactly similar to those of chloral and other narcotics, simple sleep being produced with no stage of excitement or exhilaration or intoxication so called. It was not sufficiently recognised how often alcohol acted thus in man as a pure depressant. The environment of social surroundings was largely responsible for the liveliness, physical excitement, and loquacity caused by drinking alcohol in company with others. In hospitals no such excitement or exhilaration generally appeared after the administration of alcohol. The effect of alcohol on the brain was capable of two explanations—namely, the view, at first sight appearing to be the more natural one, that it first stimulated the cerebral cells to greater activity and then depressed them, like strychnine; and the view, supported by the majority of experimental observers, that the stimulation of the brain was only apparent, and that the excitement was caused by a loss of the associations which ordinarily retarded the expression of mental activity. To adopt the mechanical simile of the brain being like an engine fitted with powerful brakes, the more closely one examined the engine the more evident it became that what appeared to be the result of increased motive power was really the effect of the removal of the brakes. It was generally recognised that some of the highest functions of the brain were thrown out of action by alcohol administered in quantities which induced the phase of exhilaration. The further question was, What functions were actually increased in activity, and how far was this increase dependent upon the reduced activity of the processes which were depressed by alcohol? Many valuable experiments had shown, in this respect, that those mental processes which were ordinarily performed readily were less retarded than those in which the subject was less practised, and which required more effort—that was, the powers most recently acquired and most readily lost were those on which alcohol first acted, while those operations which had become habitual were less impaired. This was in complete accord with what was observed in the earlier stage of intoxication or exhilaration. The most recent acquisitions in adult life were the power of self-control and the feeling of self-respect which were manifested in regard for the conventions of life, and in the prudence which led one to avoid many procedures which in earlier life one might have indulged in without reproach. Under alcohol these were the first mental processes to be disordered. *In vino veritas* was the conclusion to which the latest results of experimental science had come; in intoxication, the natural man was exposed, stripped of the trammels of convention, and robbed of the fruits of experience and education. The results of these investigations on the mental state under alcohol, as well as many others not now discussed, appeared to place the theory that alcohol acted as a narcotic upon a firm basis. But this would not preclude its chief use in therapeutics, for, like opium, its chief therapeutic use was not to induce, but to repress, cerebral activity and to produce a result of cerebral depression. In this respect alcohol was in many points not inferior to other narcotics as a medical remedy. The experimental results of the effects of alcohol on the circulation would be discussed by Dr. Dixon, who suggested that alcohol might support the heart by acting as a foodstuff, and that this might increase the

blood pressure and improve the circulation. In addition to any direct action on the circulation, alcohol might prove of value in circulatory failure through its narcotic action in the same way as opium, over which it had the advantage of not inducing any embarrassment of the respiration. But, though it might be useful in therapeutics, it must not be considered as indispensable, and its use must be curtailed to the utmost limit. In some conditions, such as old age and debility, it might be justifiable to neglect its drawbacks, but it ought to be advised only with eyes open to the risks run and with the recognition that a drug was being prescribed. The laity were justified in regarding alcohol, not as a drug, but as an article of diet so long as the physicians ordered it in the casual way familiar to all. They could hardly be blamed for ignoring the evidence of danger presented daily if their scientific mentors adopted the ambiguous position of physicians who allowed it, not believing that it would do any good, but assuming that it would do no harm, and not hesitating to make that statement; and hence the medical profession could not complain if they were accused of indifference towards the greatest evil of their country and their age.

Dr. WALLER urged that a note of warning ought to be uttered—namely, that one should not take the raw data of the laboratory and put them before the public until there had been complete analysis and strict debate. There were many forms of alcohol, and their effects on the nervous tissues differed. He then described experiments on isolated muscle with brandy diluted with water and the same spirit diluted with a 10 per cent. saline solution, and showed that the latter facilitated muscular contraction; he also mentioned other experiments with the dynamograph, showing that, while alcohol sometimes might have no effect on muscular contraction, it might have at the same time considerable effect on the dissipation of heat.

Dr. RIVERS pointed out that there were two different problems—first, the determination of the effect, immediate or within a few hours, of a single dose of alcohol; and, secondly, the question whether the continuous taking of alcohol had any effect on the capacity for muscular and mental work. In experiments with the ergograph it had been found that it was necessary to eliminate certain disturbing factors, and chiefly the interest and sensory stimulation produced by the act of taking the alcohol. There was no increase in the amount of muscular work with doses of from 5 to 20 cc. of a pure alcohol when doses were given with such a disguise that the subject of the experiment was not aware that he was taking alcohol.

Dr. DIXON drew attention to the statements as to alcohol being a poison from results of experiments on protoplasmic tissue. He could similarly prove that distilled water, beef-tea, and caffeine were poisons. It was possible to distil off ethyl-alcohol from the tissues of men and animals who had never had any alcohol; and alcohol was therefore an actual constituent of all forms of living matter. The most remarkable point about alcohol was its rapid absorption from the stomach, and during absorption it assisted in the absorption of other not easily absorbable substances, including ordinary articles of food. It was absorbed and oxidised exactly as starch and sugar, and these could be replaced by alcohol as an energy-producing substance. He had been for three years working at the action of ethyl-alcohol on the circulation, and he thought he had conclusively proved that the presence of small quantities of alcohol in the blood up to 0·2 per cent. increased the amount of work and the output of blood from the heart, especially when the heart was beating quickly or failing. This small quantity facilitated the work of the heart; but very curiously the type of action was changed entirely when the amount was increased to 0·5 per cent., when the work of the heart was not facilitated. The action of a small quantity of alcohol in giving the heart a readily assimilable form of food substance was exactly similar to that of sugar, which was normally oxidised to alcohol. It was very likely that ordinary sugar in the body was not burned off directly into carbonic acid gas and water, but that it passed through a series of ferment changes of which alcohol was one, and that that was one reason why alcohol was found in the brain, liver, and tissues of the body. The fact that alcohol depressed the mental functions

constituted no reason why men should not take alcohol, for narcotics were wanted for hyperactive minds. Sugar in excess produced fatty degeneration of the tissues, as well as excess of alcohol, and cirrhosis of the liver was far rarer in Scotland than in England, while the consumption of alcohol was at least equal in proportion in the two countries. Alcohol had a special value as a food, for it was so easily absorbed. The objections to it were that it was an expensive type of food, and that it might lead to a continuous and undesirable habit. But it was a question whether this habit of taking small quantities was sufficient to justify us in completely stopping its use.

Sir VICTOR HORSLEY said that the scientific examination of alcohol should be an accurate determination of its so-called stimulating effects, and, if such really existed, how soon did the paralysing and narcotic stage begin? Dr. Dixon's results could not be accepted until it was proved that the alcohol perfused through the tissue was actually used up. Further, the well-known effect of alcohol in increasing the diastolic relaxation of the walls of the heart could not be regarded as either a stimulation effect or an advantage to the circulation. With respect to the ergograph as a method of investigation, the majority of investigators using it decided against alcohol, but he thought it was not a sufficiently delicate or accurate method. In medicine, as Dr. Sturge and he had shown in a recently published book, alcohol was during the last thirty years being given up as a stimulant, owing to its inefficiency and its serious depressant after-effects. This change of view on the part of the medical profession was a true scientific result based on many years' observation. As alcohol was thus found wanting, physiologically and therapeutically, its abolition ought to be considered from the point of view of social science. The Physical Deterioration Committee appointed by the House of Commons proved that the first greatest evil, socially, was defective housing, and that the second was alcohol. From patriotic reasons, therefore, total abstinence should be our ideal and practice. Yet the majority took alcohol for its so-called pleasurable effects, the only results of which were natural inefficiency, poverty, vice, disease, and crime.

Mr. C. J. BOND exhibited and explained a series of diagrammatic curves showing that the consumption of alcohol, which had dropped gradually at different periods between 1845 and 1900, was intimately connected with the rise and fall in the nation's commercial prosperity, and had a certain connection with the accumulating scientific evidence as to the small value of alcohol as a food. The rise and fall in its consumption also had an effect upon the number of inmates in our asylums. From 1900 to the present day there had been a continuous decline in this nation's consumption per head of alcohol, which was a tendency none ought to deplore.

Dr. REID HUNT, of Washington, described a series of experiments on young guinea-pigs, to which small doses of a few cubic centimetres of 5 or 10 per cent. alcohol solution were daily given with their food. On four generations, over a period of two years, it was shown that they grew as quickly, reached maturity as soon, were just as fertile, as were those to which alcohol was not given. There was never a symptom of intoxication, no loss of weight, and no pathological changes. The comparison was strictly analogous to human beings who were 'moderate drinkers.' Nobody seemed to have discussed deeply the question of the increased tolerance for alcohol in the bodies of animals or men who had become accustomed to its presence. There was an increased power produced on the part of the physical body to oxidise alcohol. In respect of the comparison of sugar and alcohol, however, he had found that, while sugar increased resistance to poison, alcohol lessened it. He had made experiments with guinea-pigs and acetonitril, and alcohol seemed to lessen the resistance to the formation of prussic acid from the acetonitril introduced into the body. Most probably the continued use of alcohol produced, he thought, definite physiological changes in the body processes, sometimes for good and sometimes for evil.

Dr. WALLER closed the discussion, which he characterised as having been of very great interest and importance. He hoped that at the next meeting of the Association more positive answers and more definite statistics would be given in respect of the at present doubtful questions raised. There ought to be more

knowledge of what a moderate dose of alcohol was, though he had no conception as to what constituted an 'extremely' moderate dose. He had learnt to-day that the amounts of alcohol that could be present in the blood as physiological and pathological standard amounts—viz., 0·2 per cent. and 0·5 per cent. respectively, as shown by Dr. Dixon—were strictly proportional to the amounts of 0·02 and 0·05 respectively for chloroform. He was conscious that the ethical side of the alcohol question had not been touched upon. In the present state of the matter it was the most desirable method of procedure, and was the best way by which to arrive at definite and disinterested scientific conclusions as to the results produced by alcohol upon the physical tissues of the body, and upon the heart, brain, and circulation.

TUESDAY, AUGUST 6.

Discussion on the Value of Perfusion Experiments.

The following Paper and Report were then read :—

1. *Certain Problems in Electro-physiology. By* Dr. N. H. ALCOCK.

In this paper the author considered the analysis of nerve, non-medullated and medullated nerves from the same amount being compared. It appeared that the amount of water was greater, and the total salts slightly less, in the former than in the latter. If the non-medullated nerves be considered to represent the axis-cylinders of the medullated, it follows that the concentration of salts in their structure is less than in the medullary sheath. KCl was specially considered; the amount of this is not greater than 0·1 per cent. in the axis cylinder, and this salt is present in rather less amount in the medullary sheath, although Macallum's micro-chemical reactions do not show its presence.

2. *Report on the Ductless Glands.*—See Reports, p. 400.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION.—Professor J. B. FARMER, M.A., F.R.S.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

CUSTOM has decreed that those who are charged with the responsibilities that to-day fall to my lot should endeavour to address themselves to the consideration of matters such as they may deem to be of advantage to others, or, at any rate, of interest to themselves. It is not, perhaps, always easy to combine these two courses, and if I choose the less altruistic one I experience the smaller compunction in doing so because the undisturbed repose that most Addresses enjoy when they have been decently put away between the covers of our Annual Report seems to indicate that an attempt to express the passing thought, however ephemeral its interest, may not be the worst introduction to the business of the advancement of our science.

Any attempt to give a survey of the progress and present position of botanical science, even were so large a task at all within my power, has almost ceased to be necessary, owing to the enterprise which has so admirably provided for its adequate fulfilment elsewhere. I propose, therefore, to try to put together, in a form as intelligible as I can, the result of reflections on some of the aspects of botany that are often not seriously regarded; perhaps because they belong rather to the nebulous region of speculation than to the hard (and sometimes dry) ground of accepted fact.

I am by no means blind to the risks incurred in venturing on such a course, but I believe that a glance directed, however imperfectly, towards some of the less obvious sides of our science may not be altogether futile, even though the attempts should evoke the criticism:—

Dum vitat humum, nubes et inania captat.

The problems that confront us as botanists are far more numerous and far more complex than formerly. We are attached to a science that is rapidly growing, and this rapid advance is carrying with it a process of corresponding differentiation. Some years ago a danger arose, even within this Association, that we might have replaced differentiation, that quality which distinguishes the higher organisms, by a process of fission which is more characteristic of the lower ranks of life.

The products of the threatened fission would doubtless have pursued divergent paths, and the botanist of to-day would have been the poorer for it. He would have been lost to physiology, and all that physiology implies. Happily that danger was averted; and to our lasting advantage as members of the botanical organism our science escaped disruption, and physiological investigation still continues both to inspire, and to be aided by, other branches of botanical research. A physiological conception of morphological phenomena is the one that to me

seems to afford the broadest outlook over our territory. It serves to check a tendency towards mere formalism on the one hand and to correct the not less baneful effects of a superficial teleology on the other. Both are real dangers, and we have all encountered examples of them.

In rating highly the value of maintaining a physiological attitude of mind towards the phenomena presented by the vegetable kingdom, one is mainly influenced by the logical necessity which such a position carries with it of constantly attempting to analyse our problems, as far as may be possible, into their chemical and physical components. It seems to me that this is the only really profitable method that we can bring to bear on the difficulties that lie before us, because in using it we are constantly forced to consider the *causes* which have led to the final result. Of course I am well aware that to some minds the very attempt to apply such a method beyond a very limited range may appear futile, or at least premature. But the goal of all scientific inquiry lies in the ultimate ascertaining of cause and effect, and only with this knowledge can we hope to get control over the results.

Chemistry and physics each present to their followers problems far more elementary than those with which we have to grapple; but the explanation of the great advances which these two branches have made lies essentially in the fact that an analysis of the factors involved has enabled the investigator intelligently to interfere with, and so to control, the mode of presentation of the reacting bodies to each other. And our own special problems, whether we confine ourselves to the simpler ones, or whether we approach the obscurer matters of organisation, heredity, and the like, are assuredly susceptible of a similar method of treatment. We can never expect to get further than to be able to modify the mode of presentation to each other of the materials that interact to produce what we call the manifestations of life; but the measure of our achievement will depend on the degree in which we are successful in accomplishing this.

Indeed until we have analysed the nature of the reacting bodies, and also especially the particular conditions under which the reactions themselves are conducted, we are avoiding the first steps in the direction of ultimate success. At present, when we desire to know the taxonomic value of this or that character, we are perforce largely guided by purely empirical considerations. We find, for example, that a particular structure is very constant through a group of species otherwise closely resembling each other, and we rightly (but quite empirically) regard the possession of that character as a valuable indication of affinity within that alliance. But the very same feature in other groups may be highly variable, and lack all importance in them for systematic purposes. It may be, and very probably is, optimistic to look forward to the time when we shall know *why* the character is good in one, and worthless in another, alliance. But when we do, I am convinced that the reason will be found to lie in chemical and physical causes. We are very ignorant as yet of the details, but we can nevertheless even now form a fair guess at their general nature.

In this connection I would venture to express the opinion that much real harm is done by the toleration of an uncritical habit of mind, all too common, as to the significance of structures which are regarded as adaptive responses to stimuli of various sorts. It is *not* enough to explain the appearance of a structure on the ground of its utility; properly speaking, such attempts, so far from providing any explanation, actually tend to bar the way of inquiry just where scientific investigation ought to commence.

That many of the responses to such stimuli are of a kind to render the organism 'adapted' to its environment no one, of course, will dispute; but to put forwards the *adaptedness* as an explanation of the process is both unscientific and superficial. The size and the spherical shape of duckshot are admirably adapted to the purposes for which duckshot is used; but this affords no insight into the necessary sequence of cause and effect, which makes the melted lead assume the characters in question as it falls down the shot-tower.

But many people still find consolation and satisfaction in an anthropomorphic and somewhat slipshod application of a kind of doctrine of free-will to matters

that really call for rigorous examination into the causes which, under given conditions, must inevitably and of necessity bring about their definite result.

One of the commonest responses to the stimulus of wounding in the higher plants is the formation of a layer of cork over the injured and exposed tissue. No one can deny that this is a reaction of great utility, checking as it does the undue evaporation of water and the entrance of other parasitic organisms. And yet I suppose that no one would go so far as to seriously maintain that the obviousness of these advantages satisfactorily explains *why* the cork layer is produced. It seems to me that an investigation of the real underlying conditions which govern such a modified reaction would be of immense value, and that the information we might gain therefrom as to the nature of the chemical processes involved would prove to be of first-rate importance in tracking to their sources some of the factors that influence the course of carbohydrate metabolism within the cell. Again, we know how easy it is to produce colour-changes in the leaves of certain plants—*e.g.*, rhubarb—by severing the vascular bundles, and thereby interfering with the process of translocation. Overton has shown how the accumulation of soluble carbohydrates within the leaf of such a plant as Hydrocharis modifies the metabolic processes within the cells. Thus in bright light, under conditions of cold sufficient to arrest starch formation, but not enough to stop photosynthesis, a red-coloured substance makes its appearance in the cell, and this again disappears on raising the temperature, so that the accumulation of soluble carbohydrates diminishes. The red colour which is associated with the change may possibly by absorbing the heat ray aid in restoring metabolism to its 'normal' course; but such a teleological explanation is not of general application, and gives no real insight into the nature of the processes involved. The well-known laboratory method, which we owe to Klebs, of inducing Eurotium to enter on a sexual phase by keeping it at a temperature of 26° C. is another example of the same order. The particular reaction that occurs in each of these instances is that which necessarily results under the specified conditions, and no other course of chemical change is possible.

In the last-mentioned example, Eurotium acts in a way similar to that caused by drought, only the result is more quickly produced. This perhaps indicates that we are dealing with a definite series of changes which are inhibited by the presence of too much available nutriment supplied at a temperature too low to enable it to be sufficiently rapidly altered within the organism, so as to give rise to the specific substance which is more directly responsible for the ascogonial phase of the life-history. Something of an analogous character is probably effective in the formation of 'fairy-rings,' so typical of the growth of certain agarics. This appearance of fairy-rings may be easily reproduced in artificial cultures of moulds by appropriate means. Thus if the nutriment agar be kept fairly dry, so that the rate of diffusion of soluble materials is slowed down, it is found that concentric zones of sterile and sporiferous hyphæ regularly alternate with each other. An explanation of this behaviour, which seems most probable, is that the hyphæ, after they have been growing over the substratum for a certain distance, have acquired sufficient raw material to provide for the building-up of the substance which stimulates spore-production. When this has taken place the substance so elaborated is used up, and spore-production ceases until a fresh supply of material, under the conditions of the experiment, has been formed to act in its turn as a new stimulus. This suggestion is supported by the interference with the circular form of zones that can be brought about by artificially interfering with the rate of diffusion of the supply of nutriment in the jelly. The rhythmical alternation of sterile and fertile zones seems to prove that *quantity* of elaborated material is an essential factor in the process, just as in the stimulation of a motile organ the stimulus itself has to reach a certain minimal intensity in order to cause a movement.

The parallelism between the nutritive, *i.e.*, the chemical, stimulus in the case of the fungus and the minimal time-stimulus required to provoke geotropic movement is very striking. For it will be remembered that there is evidence in the latter instance also of the occurrence of a definite chemical change as the result of

the disturbance of normal gravitational relations. This finds expression in the accumulation of homogentisinic acid as the result of the formation of an anti-oxidative substance which arrests the complete disruption of tyrosin in the cells. Whether this is the immediate cause of the geotropic movement, or merely a concomitant of it, we cannot settle at present. But it is of the highest interest to know that chemical change is initiated as a result of the external gravitational impulse, even when the latter is of too short duration to produce an actual geotropic movement. And although we may not at present be able to identify the exact material which is directly concerned in these stimulatory or formative processes, we have, as it seems to me, irresistible evidence in favour of its real existence. It is more than mere analogy that leads us to believe that the various kinds of galls, for example, that may be produced on an oak leaf owe their formation to the specific interference of the secretion of the grub with the higher metabolic processes going on in the cells of the leaf.

I have alluded to the different conditions under which given reagents may interact, and these may in turn very materially affect the final result by modifying the course of the reaction itself. We are coming to realise the fact that the physical state of the cellular constituents exercise an important influence on the course of chemical activity manifested within their range. We all know what an important part water plays in ordinary chemical reactions, but the water question assumes a special prominence when the reactions are going on in a colloidal matrix, or rather in a mixture of colloids, such as the various proteins that occur in the cell. Questions of rates of diffusion, physical adsorption, and the like have to be taken into account; and beyond all these there remain the series of remarkable electrical relations which the proteins exhibit, as well as those changes in surface-tension that are, in part at least, connected with them.

It is impossible to resist the belief that a closer study of the physico-chemical changes that accompany a nuclear division will yet throw much light on the mechanics of this wonderful process. Indeed we already possess some data which are serving as starting-points for further investigation, and they have placed some of the known facts in a very suggestive light.

It has often been urged as a reproach against the histological methods employed in the study of the cell that all such investigations can, after all, only give information as to the character of coagulations or precipitations. Of course this is perfectly true; but provided we have sufficiently good grounds for enabling us to feel confident that the precipitation or coagulation faithfully maps out the positions originally occupied by the respective colloids during life, there is no real force in the objection. No one would call in question the accuracy of a photographic negative on the ground that after development it no longer consisted of the actual substances which had been formed in the film by the exposure to the action of light. All that is required is that the deposited silver shall accurately express the limits of, and be proportionate in amount to, the alteration in the composition of the salt which was produced when the plate was exposed in the camera.

Much of the general detail of a nuclear division can be followed even in the living cell, and we therefore possess direct as well as indirect means of testing the degree of accuracy with which the fixed preparation represents the original pattern of distribution of the colloids within the cell. No one who has studied the behaviour of artificially prepared mixtures of colloidal proteins and nucleins after 'fixing' and staining them can entertain reasonable doubts as to the substantial identity of the structures visible in a well-fixed cytological preparation with those present during life. For the substances, even in these artificial mixtures, keep remarkably distinct, as indeed Fischer showed some years ago.

Few things are more striking than the remarkable series of evolutions passed through by the linin, and by the chromosomes which finally emerge from it during the progress of a mitosis. We have clear evidence that the nucleus at this period is the seat of rapid chemical change. The process of distribution of the nuclein within the linin is sufficient proof in itself of this. But we have also, I believe,

evidence of physical disturbances of an electrical nature which accompany, and indeed in a measure determine, the course of mitosis. This is indicated, not only by the movements that proceed within the nucleus, and concern the linin and chromosomes, but also by the remarkable alterations in surface-tension exhibited by the nuclear membrane.

It is well known that at a certain stage of the heterotype division, for example, the chromosomes move to the periphery of the nucleus, and each one is removed as far as possible from every other chromosome. At this stage, to which Haecker has given the name of 'diakinesis,' the nucleus reaches its maximal size. Diakinesis is not the only stage in which there is an indication of repulsion between the elements of the chromatic linin. Measurements prove that all such periods of repulsion are also marked by an increase of nuclear size which is transitory, and either disappears or alters in a synchronous fashion with them. These phases of enlargement have generally been regarded as directly connected with the intake of liquid by the nucleus, due to a hypothetical change in osmotic conditions. But, so far as I am aware, no satisfactory explanation has yet been given as to why, or how, the supposed increase of osmotically active molecules within the assumed semi-permeable nuclear membrane could be effected. On the other hand, an enlargement of the surface-membrane of the nucleus would necessarily follow on the migration towards it of chromosomes or other bodies carrying similar electrical charges. For the induced charge in the particles of the membrane would of course weaken its coherence, and for the same reason that the free chromosomes repel and move away from one another.

There is evidence to show that the proteins *are* able to carry such charges, and this is a matter of the highest importance as affording a clue to many other processes in which changes of surface-tension play a part, besides those connected with nuclear division.

Not the least of the many remarkable properties exhibited by the proteins lies in their capacity of taking on either a positive or a negative charge of electricity. A clear proof of this was afforded by the beautiful experiments of Billitzer, who showed that, when so charged, the colloid moves as a whole towards one pole or the other on sending a current through the liquid in which it was suspended. At first sight it may not be easy to understand how it is possible for a colloid to receive and retain a charge under the conditions which obtain either in the solution or in the cell. It must, however, be remembered that the liquid contains electrolytes in solution also, and any disturbance in the equilibrium of the products of ionic dissociation will be accompanied by corresponding differences of potential. The most reasonable explanation of the phenomenon in question seems to be that the colloids are unequally permeable to the ions, whereby there comes to be a preponderance of one or the other group associated with the proteins. Perhaps this should be connected with the remarkable though still imperfectly understood property of adsorption which is characteristic of many colloids.

Much, however, still remains to be done before a complete survey of the electrical changes that are associated with mitosis can be made. We especially desire more complete information on the nature of the chemical processes which are involved. For it is obvious that the physical changes must ultimately be connected with the transformation of materials which goes on so energetically at these recurrent periods of nuclear activity. We do not yet know how or why the chromosomes that have been dispersed at diakinesis should again congregate on the spindle prior to their final separation. Possibly this is to be connected with the signs of disturbance in the extra-nuclear cytoplasm, which in its turn finds expression in the differentiation of the achromatic spindle. The character of this body has long aroused the suspicion that its existence is to be attributed to electrical causes. The more recent work serves to indicate that this suspicion was well founded.

The more complete study of the chemistry and physics of karyokinesis is certain to prove valuable for another reason. The successive changes which the nuclei of both animals and plants exhibit when they are undergoing division are so remarkably similar that it seems exceedingly probable that the processes actually

involved may turn out to be relatively simple, at any rate in their broader features. I mean that they probably belong to what we might term the lower grade of metabolic problems. For the great uniformity of the process as a whole, complex though it undoubtedly is, hardly suggests direct relations as existing between it and those more specialised forms of metabolism on which the properties of specific form, and such like characters, depend. This view of the matter is not in any way weakened by the fact that the materials providing for the multiplication of nuclei have themselves passed through the very highest stages of anabolic construction. There are, indeed, some grounds for believing that the composition of the higher proteins is distinctly specific for different groups of organisms; but apart from this it is difficult to resist the conviction that, in so far as its essential constituents are concerned, the nucleus is the seat of a complex organisation which is superadded to its chemical composition. But this conception of the nucleus does not affect the position of the lower-grade chemical changes, with their physical accompaniments which are periodically rendered apparent during the rhythmical series of changes that culminate in the division of the nucleus. It is true that there are some who refuse to admit the necessity of what I might perhaps call architectural complexity in protoplasm. They prefer to regard all the phenomena of organisation and heredity as the outcome of dynamical, rather than of structural, conditions. It seems to me that it is impossible to reconcile such a view with the known facts respecting the inheritance of characters, and that we are driven to postulate the existence of material units which are together responsible for the sum of the characters represented in any individual. There are grounds for believing that these entities, whatever be their nature, are doubled, and are then equally distributed to the two daughter cells at every ordinary nuclear division; and thus the properties of organisation are preserved and transmitted over and above the flux of chemical change.

Most people who have concerned themselves with cytological studies agree that the salient features of karyokinesis strongly emphasise the probability of a conservation of definite material; and that an extremely accurate distribution of it occurs where two daughter cells arise from a parent cell by division. And this inference is greatly strengthened by what occurs, more or less immediately, in connection with the formation of the sexual cells. The origin of these in all the higher animals and plants, as is well known, can invariably be traced to a nuclear division of remarkable complexity. In this, the so-called heterotype division, the special feature consists in the sorting-out of the nuclear constituents originally furnished by the two parents of the individual. This sorting or distribution takes place in such a way that each of the two daughter nuclei which arise as the result of the division receives only half the total number of chromosomes previously contributed by the two parents. The essential point of interest lies in the fact that the process does not consist in the mere halving of nuclear *substance*, but in the distribution of nuclear *constituents*. When two sexual cells which have been formed in this way unite to give rise to a new individual, the total number of nuclear chromosomes is again made good; but the resulting nuclear constitution will not exactly resemble that of either parent. That such is really the case is borne out by innumerable experiments that have been made by breeders. Furthermore the extensive investigations on the results of crosses, both in animals and plants, have confirmed the view that particular characters can be treated as entities. For they are distributed amongst the posterity of the original parents in proportions that closely approximate to mathematical expectation. In this distribution the separate characters behave independently. For instance, the green colour and round form of peas are two characters which may occur in the same or in different individuals. The numerical proportions in which they *will* appear can be foretold with a considerable degree of accuracy.

With these facts before us—and many others could be adduced, all pointing in the same direction—it is not easy to resist the conviction that within the nucleus there must exist material entities which are severally responsible for the appearance

of the characteristic traits of any given individual. The question is, What conception can we form as to their nature, and how are they able to produce the observed results? It is not necessary to discuss the evidence that the chromosomes, or the materials of which they are composed, play a most important part in connection with development. All the work of the last decades has tended to emphasise their importance in the transmission of hereditary qualities, and this is equivalent to admitting that they contain factors that determine the path of development, and are responsible for the production, from the egg, of the form and structure of the adult.

Now it is certain that it is not the *chromosome-substance acting as a whole* which is effective in those processes summed up in the term Ontogeny. It might be, and till recently was, thought that in those plants in which there is a marked alternation of generations a definite relation existed between the number of the chromosomes and the particular stage of the life-history. The double number was supposed to be essential for the sporophyte, whilst the halved number was similarly regarded as causally related with the appearance of the gametophyte or prothallial generation.

But Loeb and others had already shown that the eggs of echinoderms might be stimulated to parthenogenetic development by means other than fertilisation, and Wilson found that such larvæ only contained the half number of nuclear chromosomes, as, indeed, was only to be expected. But the idea of a close parallelism between chromosome number and the alternative phases of the life history was so deeply rooted that the full significance of Wilson's discovery was not at once grasped. The comparative neglect was, perhaps, partly justified, inasmuch as the larvæ could not be reared. It may, however, be incidentally remarked that no one, so far as I am aware, has yet succeeded in raising the *normal* echinoderm larva beyond the pluteus stage.

The investigation of cases of apospory that occur in the pteridophytes have proved that no causal relation can exist between the number of the chromosomes and the characters that distinguish the gametophyte and the sporophyte respectively. For the sporophyte may give rise to the gametophyte aposporously without any reduction, whilst the various types of apogamy with which we are now acquainted exhibit all gradations between a coalescence of more or less differentiated nuclei and the complete absence of all semblance of nuclear fusion. In the latter case, when the sporophyte springs from a gametophyte that has itself arisen after nuclear reduction, the sporophyte continues to retain the smaller number of chromosomes normally associated with the other generation only.

We thus have a complete proof that a single sexual cell which has undergone reduction in the number of its chromosomes retains, in so far as its architectural configuration is concerned, the capacity of giving rise to a plant possessed of the full complement of characters belonging to the species. But this, after all, is only what the facts of heredity might have led us to anticipate. For, whilst we are ignorant of the fundamental *significance* of the sexual fusion of the gametes, one of its most obvious *results* consists in the duplication of the primordia of the specific characters in the cells of the individual thus produced. This statement is not only in accord with results of experiments in breeding, but it is also in harmony with the essential features of the heterotype mitosis; and no other satisfactory interpretation of the latter series of phenomena has yet been found.

Furthermore, the facts of Mendelian dominance clearly show that each parent, through the gametes to which it gives rise, contributes an independent organisation responsible for at least some of its own distinctive characters, as well as for those which distinguish the species. Consequently, when two gametes fuse, the embryo will be provided with a duplicate stock of agents or primordia which determine the appearance of its own specific and individual characters. These will not always be similar in the two parents, and when this is the case it often happens that the offspring resembles one parent only in respect of a particular feature. Nevertheless the results of further breeding shows that the corresponding, but apparently lost, character only is latent, for it reappears in a proportion—and often a fixed

proportion—of the individuals of the succeeding generations. In such an example, where both agents or primordia are present, one of them lies dormant, whilst the dominant one alone influences the course of metabolic processes, and thus brings about the appearance of the character itself. The dormant primordium can be transmitted as such through many generations, betraying its existence in each by the occurrence of some individuals in which it finds its perfect expression. This happens when the opposite dominant agent or primordium has been removed from some of the gametes by the sorting-out process during the heterotype mitosis to which I have already alluded.

The particulate character of inheritance seems, as many writers have pointed out, to demand a structural organisation for its basis; and the units or primordia of which the latter is composed must be relatively permanent, inasmuch as heredity itself is so stable. The agents or primordia themselves probably act by definitely influencing the course of chemical reactions that proceed within the living protoplasm, somewhat after the fashion of the ferments. But whether this influence on the course of metabolism is to be attributed more directly to the chemical or the physical aspect of the organisation must, of course, remain an open question, though I incline to the latter alternative on grounds which I have already indicated.

The processes of the higher metabolism offer suggestive analogies with those reactions for which the ferments are responsible. In contemplating them one can hardly fail to be struck by the orderly way in which ferment succeeds ferment on an appropriate medium. Each one produces its own special change, which it is unable to carry further itself, but it thereby provides a substratum suitable for its successor. Starting, for example, with a complex substance like cane sugar, we see it acted on by a series of ferments, each the result of protoplasmic differentiation, and each one carrying the process of disintegration a little further, but strictly limited in its power to act, and only able to take the change on to a definite stage.

Everyone who has experimented with plants with the view of inducing the formation of some structure foreign to the species or individual by artificial means must have become impressed by the great difficulty of getting into touch, so to speak, with the higher metabolism at all. It is often easy enough to divert the life-history into either the vegetative or the reproductive channel, as every gardener is more or less consciously aware, and as Klebs has conclusively shown in his remarkble series of carefully conducted experiments. But even here it is sometimes difficult to exactly hit off the conditions requisite to ensure the production of one or other of the various phases of the life-history. There are many fungi, for example, which are believed to represent vegetative stages of Ascomycetes or Basidiomycetes, but it has not yet been found possible to ascertain the conditions that would cause them to form the highest fructifications. Even in simpler instances a similar difficulty is sometimes encountered. Thus *Bispora moniliforme*, a mould that often occurs on the wood and stumps of oak or hornbeam, is not readily cultivated as the Bispora form, whether it be grown on wood or on various nutritive media. The usual result of raising it under artificial conditions is to obtain a luxuriant crop of Eurotium-like mould. But the Bispora form can be reproduced from such a culture by growing it in strong solutions of cane sugar under certain conditions, all of which are not as yet understood.

I take it we shall agree that the properties of structure and form are to be interpreted as the necessary result of the action of particular substances on the protoplasm, and that these cause it to assume those definite attributes which we term specific on account of their constancy through a larger or smaller range of individuals. But this constancy of form must then be the result of a corresponding definiteness in the series of changes undergone by the raw materials supplied as food in their upward transformations; each stage in the process limits the possible range of those that follow, as in the case of the ferments to which I have alluded; and thus it becomes increasingly difficult to modify the final result.

In this way we may see, perhaps, an explanation of the circumstance that in amphibious plants the particular structure, whether adapted for land or water,

that will arise in conformity with the environment, is irrevocably determined long before the organs themselves are sufficiently developed to be exposed to the direct influence of the conditions to which they are supposed to be specially adapted.

Now it is a matter of common knowledge that the formative processes can be, and sometimes *are*, disturbed with the most surprising results. I may again refer to the fungal or insect galls as examples that will be familiar to everyone. It appears to me that these exceptional developments are of extraordinary importance in relation to any endeavour to probe the mysteries of organisation. The very difficulty experienced in imitating the effect of the insect's secretion strongly emphasises the specialised nature of the particular substance which is able to modify the 'normal' reactions of the plant. The latter are dependent on the way in which the organic apparatus determines the fashion of the molecular presentations, so that, as I have said, the course of the reactions themselves become increasingly limited in their range. Now as regards the manner in which the secretion of the insect operates, it seems clear that it can produce no permanent change in the organising apparatus of the protoplasm, since the growth is at once arrested on the removal or death of the insect. But whether the influence is one that more directly affects the physical state of the apparatus for the time being, or whether it acts more directly by introducing new substances into the final chemical reactions, are questions which are plainly worth investigation, but at present certainly do not admit of an answer.

Another example of interference with the developmental processes is afforded by the well-known 'lithium larva,' which was discovered by Herbst to arise when the eggs of some species of sea-urchins are allowed to segment in sea-water that has been altered by the addition of lithium salts. The monstrosity produced under these conditions was just as constant and specific in character as are the different galls which can be induced to develop on an oak leaf by the corresponding species of insect.

Extending these considerations a little further, one sees that what we call disease also falls into the same category. For disease represents the necessary outcome of a disturbance, however introduced, into the course of metabolism, which diverts it from the 'normal' channels. Pathology has long recognised that the explanation and the consequent control of disease lies, ultimately, in the correct appreciation of the cellular reactions as the result of their experimental study. We cannot pride ourselves on the advances that have been made in the study of plant pathology as yet. Our remedies are commonly of the crudest kind, and we have only recently begun to take serious count of the facts of organisation in the scientific attempt to breed races of plants immune from the attack of certain diseases. The results that have already been obtained, both abroad and by Biffen and others in this country, are full of hope at the present time. The study of the causes of immunity along scientific lines ought assuredly to form a fruitful field of investigation in the near future.

From what we already know it seems clear that the proximate causes of immunity may be diverse in character, and may consist in very different reactions in different cases. It may be that the response becomes expressed in a modification of the carbohydrate metabolism, leading to the formation of an excluding layer of cork; or it may lie in the direction of those substances, as yet so little understood, the anti-toxins; or, again, it may be due to still other and even less apparent causes. But whatever the true nature of the response, it will have to be investigated for individual cases, and its secrets will only be unlocked when the chemical and physical processes involved in its operation are understood.

In making these remarks I dare say I may be accused of putting forward an impossible ideal, or at any rate one that is impracticable of attainment. I am not very much concerned about that. Progress is only to be made by trying to penetrate further than we can at present see, and I believe we have gained enough insight into the chemistry and physics of the living processes to warrant us in hoping that we shall penetrate a good deal deeper still. But if we are to ever unravel the tangle, it can only be by applying such methods as have been successful in dealing with material things elsewhere.

For the problems that rise up before us are seen, as we become able to get at close quarters with them, to resolve themselves more and more into questions of chemistry and physics. I believe that it is only by the help of these elder branches of science that the accurate formulation, to say nothing of the final solution, of the problems will be achieved. A recent writer has suggested that life is not the cause of the reactions underlying the phenomena of life. Nevertheless the reactions that go on in the living body are obviously guided as to the particular directions they take by the apparatus or mechanism of the individual organism. When the conditions for the manifestation of life, and all that it implies, are satisfied, what will be produced depends partly on the structure of the apparatus itself (*i.e.*, on the hereditary organisation), partly on the nature of the substances fed into the apparatus, and finally on the physical conditions under which it is working. It is probably along the last two lines that investigation will continue to be pursued with more immediate profit; but the goal will not be finally reached till we have solved the problem as to the nature of organisation itself.

The following Papers and Reports were then read:—

1. *Charnwood Forest.* *By* William Bell.

The paper dealt with the situation, original boundary, physical features (undoubtedly caused by volcanic action), inhabitants—people, animals, birds, &c.—and the vegetation of Charnwood Forest.

The original flora can be to some extent restored by the extension of the vegetation found in the undisturbed country round Groby Pool to those parts of the forest which exhibit similar physical features.

There is a suggestion of an alpine or sub-alpine flora by the survival of such plants as *Empetrum nigrum*, *Cotyledon umbilicus*, &c.

There has been a gradual contraction of the forest area with the vanishing of the woodland and bog. Edward I. gave permission for a park to be enclosed from Charnwood Forest. There is strong reason to believe that a stretch of country reaching from the River Soar, near Birstall, along the southern side, and on the western side right up to the border of Derbyshire, were so enclosed. If so, the ramifications of the forest reached considerably further than is generally held at the present day, and in fact joined up to the Leicester Forest. Further contraction of the area was brought about by the allotments to the various adjoining parishes and the claims or gifts to the various religious orders who built abbeys and priories in and on the borders of Charnwood; and the final enclosure of the remainder, sanctioned by an Act of Parliament in 1808, which became effective in 1829.

The chief features of the woodland are oak, birch, beech, fir, ash, elm, &c.; but the gradual clearance of all timber from the forest for building, naval, and fuel purposes led to the practical absence of timber for about two centuries, though there has been partial reafforestation.

Dr. Richard Pulteney's (1746) list of plants found in the neighbourhood of Loughborough contains 313 records undoubtedly referring to Charnwood Forest; a comparison of these records is made with the later ones of Bloxam and Coleman, Mary Kirby, and the 'Flora of Leicestershire' (1886), and with our recent personal experience of plants on the forest area.

Tables were given, showing the increase or decrease in quantity or number of stations of the plants named by Pulteney, and demonstrating the change in the character of the flora by subdividing the plants which exhibit a change into woodland, bank, rock, bog, water, heath, and field (arable and pasture) forms.

Some features of the present flora were illustrated by lantern-slides and maps.

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2. *On the Disappearance of certain Cryptogamic Plants from Charnwood Forest, Leicestershire, within historic times. By* A. R. Horwood.

Like some phanerogams formerly found within the boundary of the historic Charnwood Forest, Leicestershire, there are many cryptogams which have become extinct within the last century.

Amongst these last the lichens, hepatics, and mosses have received most attention from a systematic point of view locally, and the communication referred mainly to those plants.

It may be stated, however, that, as a general rule applying to all the Cryptogamia, certain plants are confined, in the Leicestershire district, to Charnwood Forest. From various causes a considerable number have disappeared from that region. The principal of these are (*a*) the drainage and disforestation of the forest, and (*b*) the increased amount of smoke resulting from the ever-growing number of colliery and other workings in the neighbourhood, causing the diffusion of sulphurous gases, which are detrimental to the growth of plants, affecting principally their leaves or vegetative organs. Lichens are especially susceptible to this new poisoning agent, and it does not seem to have hitherto been placed on record how widespread is the extermination of the lichens of Great Britain.[1] As a result, numerous species and genera have become extinct, and many plants are found to be imperfectly developed. According to the Rev. H. P. Reader, who first pointed out this fact to the author, the approaching disappearance of all but the hardiest lichens is not confined to Leicestershire, nor even to the manufacturing districts of Central England, but is noticeable also in the less populated portions of the South of England.

A summary of the cryptogamic plants that have become extinct in Leicestershire was given, which included not only a large number of the rarer and more interesting lichens, but a considerable number of species of hepatics and mosses.

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3. *On the Cotyledon of* Sorghum *as a Sense Organ. By* Francis Darwin, *F.R.S.*

The observations here given are supplementary to the paper on Geotropism and the Localisation of the Sensitive Region read before Section K in 1899 and published in the 'Annals of Botany,' vol. xiii.

The method employed is a modification of Czapek's well-known experiment on roots in which the organ is bent by being allowed to grow into a curved glass tube. In my work, the cotyledon of *Sorghum* is forcibly bent close to the base and fixed in that position to a vertical plate of cork. It was found that this treatment produces a traumatic effect on the hypocotyl which tends to curve in the direction of the bend impressed on the cotyledon. The seedlings can be fixed in two positions: in one (No. 1) the traumatic effect is added to the geotropic stimulus which according to my experiments of 1899 originates in the cotyledon; in position 2 the traumatic effect and the cotyledonary stimulus are opposed to each other. In position 1 the curvature of the hypocotyl is always in the direction which would be accounted for if the cotyledon were the sense organ for gravity. In position 2 the results were irregular, no doubt owing to the opposition of the sraumatic effect. This result is not conclusive, but it should be noted that if the teat of geo-perception were exclusively in the hypocotyl the results must have been reversed—a curvature should have occurred regularly in position 2, while the curvatures should have occurred irregularly in position 1. The conclusion that geo-perception occurs in the cotyledon is confirmed by using the method which Piccard employed in the case of roots. *Sorghum* seedlings are fixed by their cotyledons to a Knight's machine (having a horizontal axis) so that the cotyledon and hypocotyl are exposed to opposing centrifugal stimuli. This is effected by arranging the seedling so that the junction of the cotyledon with the hypocotyl

[1] But see a paper read at the Bradford meeting, 1900, by Mr. Albert Wilson, dealing with the same question.

is in line with the axis of rotation: under these conditions the hypocotyl curves away from the centre in obedience to the stimulus arising in the cotyledon. If geo-perception were confined to the hypocotyl the curvature must have been towards the centre.

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4. *A Botanical Excursion in the Welwitschia Desert.* *By* Professor H. H. W. PEARSON, *Sc.D., F.L.S.*

Welwitschia is confined to the littoral strip of desert which, commencing near the mouth of the Orange River, extends northwards far into the tropics. The paper records observations [1] made in 1907 in the neighbourhood of Haikamchab and Welwitsch, situated in the most southern area from which the plant is known.

The flora of the desert belt (the 'Namib') is of a marked desert type, mainly characterised by several highly peculiar and endemic forms. The western fringe of the Namib is occupied by sand-dunes, some of which are as much as 200 feet high. Their vegetation is very scanty, and it appears that the whole phanerogamic flora of the dunes of Walfisch Bay comprises no more than a dozen species. Of these, two are of special interest, viz., *Acanthosicyos horrida* and *Tamarix articulata*. The former, a member of the Cucurbitaceæ, is well adapted to growth in accumulations of sand, and many of the large dunes owe their stability, and indeed their existence, to this plant, whose deep roots serve as anchors.

East of the sand-dunes, where the surface is hard, the flora is richer in species, though in many localities considerable areas are quite destitute of flowering plants. The vegetation consists chiefly of deep-rooted woody perennials of low habit and with small leaves. Among these are *Zygophyllum Stapfii*, a very characteristic Namib plant, and one of the surprisingly few succulents met with, *Commiphora saxicola*, *Sarcocaulon* sp., whose stems are encased in an armour of hard wax, a Bauhinia, a few Capparidaceæ and Blepharids. The grasses are rather numerously represented in sandy places by species of Aristida, and prostrate Cucurbitaceæ are not infrequent. The arborescent *Aloe dichotoma* is common among the barren crags of the broken country overlooking the main river-beds.

Welwitschia occurs abundantly on the Namib plateau, and descends the ravines leading down to the deeper river-channels. Its altitudinal range is about 400 feet. A number of photographs illustrating the habit of the plant, its inflorescences, cones and flowers, were shown. Pollination is mainly, if not entirely, effected by the hemipteron *Odontopus sexpunctulatus*, as has already been described.[2] Subfoliar inflorescences commonly occur.

Fertilisation rarely fails, and very large numbers of fertile seeds are produced. No germinating seeds nor young seedlings were found, and it appears that the conditions necessary for effective reproduction rarely occur.

The Namib flora must be regarded as of great age, and it must be supposed that the climatic conditions at present prevailing in South-west Africa, especially the distribution of the rainfall, have, in their mean features, been permanent for an enormously long period. Although now so distinct the flora is probably derived from the same stock as the Acacia formation which flourishes to the east of it, and which in a former period may perhaps have extended considerably to the west of its present limit.

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5. *Report on the Registration of Botanical Photographs.*

See Reports, p. 417.

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6. *Report on Research on South African Cycads and on Welwitschia.*

See Reports, p. 408.

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[1] Assisted by a grant from the British Association.

[2] *Nature*, vol. lxxv. pp. 536, 537.

7. *Third Interim Report on the Structure of Fossil Plants.*
See Reports, p. 408.

8. *Report on Peat Moss Deposits.*—See Reports, p. 410.

9. *Report on Studies of Marsh Vegetation.*—See Reports, p. 409.

10. *Report on Experimental Studies in the Physiology of Heredity.*
See Reports, p. 410.

11. *The Preservation of Natural Monuments. By* Professor CONWENTZ.

FRIDAY, AUGUST 2.

The following Papers were read:—

1. *The Embryology of Pteridophytes. By* Professor F. O. BOWER, *F.R.S.*

Comparative embryology of the sporophyte stands at the moment in a discredited position as compared with other avenues to an opinion on the phylogeny of Pteridophytes. The chief reasons for this are:—

1. Distrust of segmentation as bearing any constant relation to the genesis of parts.
2. The apparent inconstancy of position and of number of the parts in embryos of near affinity, *e.g.*, in the different species of *Lycopodium.*
3. The obvious physiological opportunism which dominates the development of certain embryos, notably those of the Leptosporangiate ferns.
4. The inconstancy of the occurrence of a suspensor, and of certain tuberous and suctorial swellings.

The position commonly held at the moment is that stated by Goebel,[1] that 'root, shoot, and haustorium are laid down in the positions that are most beneficial for their function.' This implies that there is no generally constant feature in the conformation of embryos in vascular plants. To those who accept this as true, embryology cannot form a secure basis for general comparisons, or for phylogenetic argument.

A revision of the embryology in the whole series of Pteridophytes, in which the facts relating to the Psilotaceæ form now the only conspicuous gap, has led to the conclusion that the form is not so inchoate as Goebel's statement implies. There is one point comparable in them all, which does not appear susceptible of disturbance on a basis of opportunism—viz., the position of the apex of the axis relatively to the primary segmentation. The position, number, and time of origin of the primordial leaves may vary, roots may also vary in number and position and time of appearance, and haustoria and tuberous swellings may be large or small, present or absent, but a comparison of embryos shows that the apex of the axis bears a constant position in the epibasal hemisphere.

The time of initiation of the epibasal hemisphere varies according to the presence or absence of a suspensor, and in different types it may be directed towards, or away from, the archegonial neck. But whatever these variants, the apex of the definitive axis lies at a point coincident with, or in very near proximity

[1] Organography II., p. 246.

to, the intersection of the octant walls of the epibasal hemisphere. The position of the apex of the axis defines the polarity of the embryo; and as its position relatively to the basal wall is constant, that wall is itself the early indication of that polarity.

There are two or three sources of disturbance, which veil the recognition of the polarity thus noted, as a constant feature in embryos:—

1. The initial polarity is apt to be inverted, and evidence of such inversion may be found within definite phyla. Examples will be quoted in Lycopodiales (*Selaginella* and *Isoëtes*); in Ferns (Marattiaceæ and Leptosporangiates); in Ophioglossaceæ (*Ophioglossum* and certain species of *Botrychium*).

2. Certain parts may be hastened forward in their development, or delayed, according to biological requirements. If leaves be precocious, the axis is apt to be delayed or dormant; but where most insignificant its constancy of position is indicated by the orientation of the leaves.

3. Parenchymatous swellings may be formed of the nature of a 'protocorm' or of an haustorium (foot); these may distort the embryo in a high degree, and mask the relation of the ultimate shoot-apex relatively to the initial segmentation (e.g., *Lyc. cernuum*). But it is believed that in all cases that relation really exists

The definition of such a polarity in the embryo presents it to the mind as a spindle of varying proportion upon which appendages may be borne This is the obvious condition in *Equisetum*—the only one of the strobiloid sporangiophoric Pteridophytes in which the embryology is known. The condition of other embryos, even the most divergent, is believed to be due to modifications of a similar construction, susceptible of biological explanation. In extreme cases, such as certain Lycopods, a peculiar embryologic phase—the protocorm—thus precedes the regular vegetative shoot: this is held to be the result of a secondary specialisation. In others, such as *L. Selago* and *Phlegmaria*, the development passes directly to a condition characteristic of the permanent shoot; these are believed to reflect more nearly the primitive history. In Ferns, as also in *Isoëtes*, the early polarity of the embryo is marked by the precocious development of the cotyledon. In Ophioglossaceæ this precocity varies in a high degree, and in many of them it is the root which is precocious, while the first leaves may be developed sometimes as insignificant scales. But under all these diverse proportions the embryo is so constructed that the apex of the axis originates at, or in near proximity to, the centre of the epibasal hemisphere.

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2. *Joint Discussion with Section D on the Physical Basis of Heredity.* *Opened by* Professor S. J. Hickson.—See p. 541.

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3. *Some Advances in our Knowledge of the Pollination of Flowers.* *By* Professor F. E. Weiss, *D.Sc.*

MONDAY, AUGUST 5.

The following Papers were read:—

1. *The Morphology of* Aspergillus herbariorum. *By* Miss H. C. I. Fraser *and* H. S. Chambers.

Aspergillus herbariorum was first studied by De Bary in 1863. His investigations were non-cytological, and in view of the very common occurrence of this fungus further knowledge of its development was felt to be desirable. Cultures were made on 3 per cent. agar-agar mixed with prune juice and cane sugar.

The archicarp is more or less coiled, and is divided into three parts, all multinucleate. The apex of the coil forms a unicellular trichogyne; below this is a considerably longer unicellular ascogonium, and below again a septate stalk.

An antheridium is usually developed; when present it either becomes continuous with the trichogyne or degenerates before reaching this stage.

We were not able to trace the breaking down of the wall between the trichogyne and ascogonium, but we think it probable that normal fertilisation sometimes takes place. In the absence of this process we infer that a form of reduced fertilisation occurs, similar to that observed by one of us in *Lachnea stercorea*.

After fertilisation or its equivalent has taken place, sheathing hyphæ grow around the archicarp, arising mainly from the cells of the stalk. They eventually form two layers—the outer protective, the inner nutritive. The ascogonium becomes septate and its cells branch, giving rise to ascogenous hyphæ. These grow irregularly among the nutritive cells and produce asci. The nuclei of the ascogenous hyphæ are often in pairs. Fusion of two nuclei occurs in the ascus. This is followed by three karyokinetic divisions, and eight spores are produced. Pairs of confluent ascocarps were occasionally seen.

Recent observations on *Eremascus* (Stoppel, 1907) have brought into renewed prominence the question of the phylogeny of the Ascomycetes. The genus *Aspergillus* is no doubt primitive; its antheridium and archicarp (still more, perhaps, those of *Penicillium*) recall the 'copulating hyphæ' of *Eremascus*. In another direction it may be related to *Boudiera*, the paired ascocarps forming a possible step towards the compound arrangement normal in that genus. Recent work (Claussen, 1907) has approximated *Boudiera* and *Pyronema*. The spermatia and the septate archicarps of the Lichens and Pyrenomycetes may also be related to the sexual organs of *Aspergillus*. In this genus, as in *Sphærotheca*, the antheridium develops as a hypha, at the end of which an antheridial cell is cut off. If this cell, instead of fusing with a neighbouring archicarp, were set free from its parent hypha it would scarcely differ from a spermatium. In *Nemalion* (Wolfe, 1904), among the Red Algæ, the so-called spermatium is actually an antheridium, and still contains two nuclei.

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2. *Fertilisation in* Ascobolus furfuraceus (*Pers.*). *By* E. J. Welsford.

The development of *Ascobolus furfuraceus* was first described in 1871 by Janczewski, and since then has been more fully investigated by Harper and by Dangeard.

The ascocarp in its early stages consists of a scolecite of from six to ten cells, arising from a dense tangle of multinucleate hyphæ, and is rapidly covered by a hyphal sheath. The cells of the scolecite are at first uninucleate, but they soon increase in size and become multinucleate; one of them, generally that fourth from the apex, is larger than the others, and gives rise to the ascogenous branches. Large circular pores are present in the transverse walls of the scolecite, and through these the nuclei and cytoplasm of the neighbouring cells migrate into the large cell. Here they fuse in pairs, and the fusion nuclei eventually pass into the ascogenous hyphæ, which by this time have grown out from all parts of the ascogenous cell. Asci arise as branches of these hyphæ and the ascogenous cell is soon emptied of its contents.

The process of syngamy in *Ascobolus furfuraceus* is evidently of a reduced type, since a male organ is not present. Fusion in pairs of the nuclei of the scolecite, however, takes place. The ascogenous cell in which this occurs is obviously female. If the neighbouring cells of the scolecite be placed in the same category, the sexual fusion in *Ascobolus furfuraceus* closely resembles that in *Humaria granulata*; if, on the other hand, these supernumerary cells be regarded as vegetative, the form of syngamy approximates to that observed in such of the Uredineæ as *Phragmidium violaceum*.

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3. *Nuclear Fusions and Reductions in the Ascomycetes.* *By* Miss H. C. I. Fraser.

The following observations were made primarily on *Humaria rutilans*, a small orange Discomycete with exceptionally large nuclei.

The ascocarp originates as a tangle of septate hyphæ among which sexual organs are not differentiated. Normal fertilisation is replaced by the fusion of vegetative nuclei in pairs, occasionally preceded by migration. The process is quite analogous to that which takes place in 'pseudapogamous' fern prothallia,[1] and probably also in certain Uredineæ,[2] and in the Basidiomycetes. Cells containing fusion-nuclei give rise to sporophytic or ascogenous hyphæ; those in which fusion has not taken place produce the paraphyses and other gametophytic structures. Divisions in the sporophytic hyphæ show sixteen chromosomes. Asci are formed in the usual way, but since the terminal cell continues its growth, they are regarded as lateral branches of the ascogenous hyphæ.

After it is cut off, the two nuclei of the ascus enter independently on the prophases of a heterotype division. They fuse soon after the stage of the first contraction. Fusion is regarded as brought about by their close proximity at a time when the nuclear membrane is breaking down; occasionally it fails to take place. The subsequent stages of the first and second mitoses in the ascus are in agreement with those described by Farmer and Moore (1905) for the reducing divisions of various animals and plants; the chromosomes divide *transversely* in the heterotype.

The chromosomes throughout the meiotic phase are sixteen in number; but since sixteen is the diplocytic number and, at this stage, the reduced number is typically present, they are regarded as representing two gametophytic sets of chromosomes. Fusion in the ascus thus results in the doubling of the chromosomes.

In the prophase of the third division sixteen chromosomes appear; they separate without fusion, so that only eight pass to each daughter nucleus. A second reduction is thus brought about, and the true gametophytic number of chromosomes is restored. Probably the extraordinary regularity with which two fusions occur in the life history of the Ascomycetes is due to the establishment of two reductions in the ascus.

In all investigated organisms the meiotic phase is related to fertilisation or its equivalent; the simpler reduction of the third division is held to be connected with the fusion in the ascus. It is probable that a reduction of this type compensates other asexual fusions also.

A method of distinguishing between sexual and asexual fusions is thus suggested.

The processes in the ascus of *H. rutilans* are related to those observed in *Phyllactinia*[3] and the few other Ascomycetes studied from this point of view. There is reason to believe that a sorting of the chromosomes, analogous to that seen in meiosis, takes place in the third division of the ascus; the most essential difference between the two reductions seems thus to lie in the more complex prophases of the heterotype division and particularly in the characteristic contraction of the chromatin.

Spore formation was also studied; the general appearance was that described by Harper, but neighbouring vacuoles take part in the process.

The main observations on *H. rutilans* and especially those relating to the third division in the ascus have been confirmed by the author in conjunction with Miss E. J. Welsford for *Peziza aurantia*.

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4. *Enzymes: their Mode of Action and Functions.*
By Professor H. E. Armstrong, *F.R.S.*, and Dr. E. F. Armstrong.

Joint Discussion with Sections D and L on the Teaching of Biology in Schools.—See p. 547.

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[1] Farmer and Digby, 1907 [2] Blackman and Fraser, 1906 [3] Harper, 1905.

TUESDAY, AUGUST 6.

The following Papers were read:—

1. *The Real Nature of the so-called Tracheids of Ferns.* *By* D. T. Gwynne Vaughan, *M.A.*

The metaxylem elements of the Osmundaceæ, both recent and fossil, are not tracheids, but form a special and peculiar type of vessel. The pits, both in the end and in the lateral walls, are true perforations, and usually more than one series of pits occurs on the same side of the wall. Further, there is no middle substance in the median plane of the wall joining together the pairs of bars of thickening that separate the corresponding pits of two adjoining tracheids. There is therefore a cavity or free passage up and down connecting each vertical series of pits in the middle of the substance of the wall.

These cavities arise by the re-absorption in these regions of the whole of the primary wall of the young tracheæ. The same type of element seems to be widely spread among the other orders of the Pteridophyta.

2. *On the Structure and Affinities of* Physostoma elegans *(Williamson), a Pteridospermous Seed from the Coal Measures.* *By* Professor F. W. Oliver, *F.R.S.*

The diversity of form usually met with in a modern group of plants, such as a natural order of Angiosperms, is of great assistance in determining the affinities of the group. The differing floral characters of a series of allied genera, for instance, furnish the data upon which judgments can be based as to the probable line or lines of floral evolution within and even beyond the limits of the order. In this respect the palæo-botanist who studies petrifactions is at a disadvantage owing to the very isolated and specialised character of the floras that are available. Thus the position in regard to the coal-measure flora is somewhat analogous to that which would obtain in regard to the existing flora were the latter represented by a portion of a single forest and a salt-marsh. Or, to put the matter in a slightly different way, our carboniferous petrifactions are largely isolated and often special types comparable with *Ginkgo*, *Welwitschia*, and *Taxus* in the existing flora.

In these circumstances, in the rare cases in which a series of allied forms is available, the detailed comparison of its members is most desirable. Such a series is afforded by the Lagenostoma-group of pteridospermous seeds of which the seed *Physostoma elegans*[1] is one of the representatives. The present paper deals with Physostoma and with a consideration of its relationship to the Lagenostomas. The seed is quite exceptional among structures of this class in the *ensemble* of unique and curious characters which it presents. The grounds are considered fully for regarding it as the most primitive of the pteridospermous seeds that have yet come under observation.

3. *On the Cone of* Bothrodendron mundum. *By* D. M. S. Watson, *B.Sc.*

The small cone described by Williamson in 1880, part x. of his 'Memoirs on the Organisation of the Fossil Plants of the Coal Measures,' pl. 15, fig. 8, has been obtained in transverse section by the author. The wood of its axis agrees exactly with that of *Bothrodendron mundum* (Will.).

[1] This name was originally proposed by the late Professor W. C. Williamson for the seed which, owing to the imperfect material then available, he afterwards called *Lagenostoma physoides*. The time has now arrived when effect may be given to Williamson's original intention.

The whole cone is very small and weakly constructed.

It is found to be hermaphrodite, the microspores being at the top, where the cone is smaller in diameter than in the lower macro-sporangiate region.

The macro- and micro-sporangia and their sporophylls have the same structure.

In each case the radial extension of the sporophyll is very slight; the sporangium is attached to the middle of the horizontal portion by a narrow circular neck of tissue.

Between this attachment and the upturned lamina is a large ligule. The base of this is surrounded by transfusion tissue of the ordinary type.

The macrospores occur four in each sporangium, and are characterised by bearing long branched spines.

The micro-sporangia when isolated have been often confused with those of Miadesmia.

They are shown to belong to this *Bothrodendron* cone by comparison with attached examples and with detached macro-sporangia, with which they agree perfectly in structure.

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4. *On the Hairiness of certain Marsh Plants.* *By* Professor R. H. Yapp, *M.A.*

In contrast to true aquatics, a large number of marsh plants possess more or less abundant hairs on their leaves and other parts. In some cases the hairs are sparse; in others (e.g., *Spiræa ulmaria*) the hairs form a dense felt on the under-surfaces of the leaves. But in the leaves of many species there are marked seasonal differences in this and other respects. Thus in *Mentha aquatica, Lysimachia vulgaris, Epilobium hirsutum, Spiræa ulmaria,* and other species, the first-formed leaves of the year are small and glabrous, while the later-formed leaves are larger and more hairy. As a general rule the low-growing shoots have either glabrous or only slightly hairy leaves, while the taller, erect shoots are more hairy.

Spiræa ulmaria is especially striking in this respect. It forms in the spring-time successively glabrous, partially hairy, and hairy leaves, the pubescence on the latter being exceedingly dense, particularly in the case of the leaves on the erect flowering stems. The distribution of the hairs on the partially hairy leaves is interesting, and seems to follow quite definite rules. Thus (1) in a partially hairy leaf the terminal leaflet is always the most hairy, the pubescence on the other leaflets decreasing from above downwards; while (2) in a partially hairy leaflet the pubescence first appears round the edges of the leaflet, or sometimes in well-marked bands between the main veins.

Now, there exists an entirely glabrous form of *Spiræa ulmaria*, the so-called var. *denudata*, which, so far as my own experience goes, occurs in Nature only in quite sheltered places. On growing this variety in situations exposed to strong winds it appears to suffer more from the exposure than the ordinary hairy form. The effect of such exposure is that the leaves soon become partially withered, the distribution of the withered parts very nearly coinciding with the distribution of hairs on a partially hairy leaf of the ordinary variety; that is to say, the most vulnerable parts of the leaves are precisely those parts on which hairs first appear in a partially hairy leaf.

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5. **On the Inheritance of certain Characters in* Primula sinensis. *By* R. P. Gregory, *M.A.*

The primary object of these experiments, begun in 1903 by Mr. Bateson and the writer, upon *Primula sinensis* and other heterostyled plants, was the investigation of the inheritance of the characters of long and short style. In a previous communication [1] we showed that the inheritance of these characters is Mendelian,

[1] *Brit. Assoc. Rep.*, 1905; *Roy. Soc. Proc.*, B, vol. lxxvi., 1905.

the short-styled or thrum-eyed form being dominant over the long styled (pin-eye(form. Subsequent experiments have confirmed this, and the larger numbers no obtained approximate closely to the theoretical ratios, although in particular cas discrepancies sometimes occur.

In the case of one race of plants the results of our ear' experiment appeared to indicate an interesting departure from the norm... Used as male parents, these plants gave results consistent with the gametic constitution DD, while used as female parents they appeared to be heterozygous. This case has been followed up, but in all the offspring the peculiarity was found to have disappeared, all the plants used proving to be pure in respect of the short style (DD).

Other characters which have been investigated are the form of the leaf, the presence or absence of the large yellow 'eye' in the flower, the colour of the stem and petioles, and the colour of the flower.

Of these the first gives simple Mendelian results, the palmate character of the leaf being dominant to the fern leaf. In some cases a form of leaf somewhat intermediate in character between the palmate and fern-leaf types occurs. We conjecture that this type may be of a heterozygous nature.

The large yellow 'eye' may occur in thrum-eyed or non-thrum plants. It is a recessive character, rendered interesting by the fact that when it occurs in a plant which is not a thrum the style does not project above the level of the anthers, although the position of the anthers and the size of the pollen, as well as the results of breeding experiments, pro... it to be a long-styled plant.

As regards the colour of the stem and petioles, both may be green, or red pigment may be present, which varies in intensity and distribution in different races. The red colour may be confined to a faint appearance of red round the 'collar,' the stems being green; the stems may be light red, with or without a darker 'collar'; or the stems and collar may be a deep red. The colour of the stem is therefore determined by two (and perhaps more) pairs of allelomorphic characters.

The colour of the flowers presents a very complex problem, and we are still very far from its complete elucidation. Perhaps the most interesting result at present definitely attained is the discovery of two distinct classes of whites. One race of white-flowered plants with pure green stems (Sutton's 'Snowdrift') proves to be a true albino, being devoid of any colouring pigment. But in all the other races of white-flowered plants examined a character occurs which must be looked upon as inhibiting the development in the flower of a colour which is potentially present in the plant. These white plants all show red pigment in the stem, although it may be confined to the merest trace of colour at the collar.

'Snowdrift' crossed by a form with coloured flowers gives a coloured F_1. The 'Dominant Whites' crossed by the paler colours give in F_1 white flowers, and crossed by the forms possessing full-coloured flowers give tinged white in F_1. In F_2 these tinged whites break up into a long series of coloured, tinged, and white forms.

The offspring of the 'Dominant Whites' × 'Snowdrift' possess white flowers (F_1), and in F_2 give whites and coloured forms. The appearance of coloured flowers in F_2 may be explained from the gametic constitution of the parents. The 'Dominant White' possesses both inhibition and colour (DC); 'Snowdrift' possesses neither (dc). In the F_2 of such a cross three plants out of sixteen will be of the constitution (dC), and will therefore show colour in the flowers. The character of the colour depends on the particular race of 'Dominant White' used in the experiment. From the results at present obtained one may perhaps say that when the 'Dominant White' has a red collar only, the stems otherwise being green, the colour which appears in F_2 is a pale pink. When the 'Dominant White' is one which possesses deeper colour in the stem, magenta-flowered plants, as well as pale-pinks, appear in F_2. In both cases the pale-pink flowers are always borne on plants with red only in the collar, the magenta flowers on plants with red or full-red stems.

This is an instance of the coupling between the colour of the flower and the

presence of colour in the stem which is found to hold good also in the case of plants of other races than those just described. Whether this coupling is simply zygotic or whether it may sometimes be gametic is not yet clear.

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6. *The Phylogenetic Connexions of the recent Addition to the Thread Bacteria* (Spirophyllum ferrugineum [*Ellis*]). *By* DAVID ELLIS.

This new species, discovered in the iron-waters of Renfrewshire, and since found to be fairly well distributed throughout the west of Scotland, is phylogenetically interesting because it links the iron-bacteria with the genus Spiromonas, which has hitherto been thrust out of the bacteria-group, but inserted in Migula's classification as a dependent. Spirophyllum agrees with Spiromonas in possessing a flattened body thickened at the edge in the same way. Both are also spirally twisted, but whereas Spiromonas never shows more than one and a quarter turns, and is motile in the mature condition, Spirophyllum may exhibit any number of turns, and is only slightly motile immediately subsequent to germination. Whilst the relationship between these two genera is undoubted, it is equally certain that the new genus Spirophyllum is very closely allied to the other iron-bacteria on account of the similarity in their mode of life, their mode of deposition of iron, and more especially in their mode of reproduction. It therefore seems desirable to alter slightly the definition of the order Chlamydo-bacteriaceæ (Migula's classification), so as to include both Spiromonas and Spirophyllum. This could be done by inserting 'cylindrical or flat cells, usually surrounded by a limiting membrane,' instead of 'cylindrical cells, arranged in threads, and surrounded by a limiting membrane.'

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7. *The Structure of Root Tubercles in Leguminous and other Plants. By* Professor W. B. BOTTOMLEY.

The root-tubercles in all leguminous plants examined appear to arise endogenously from the cortical cells just outside the endodermis of the root. These cells are stimulated by the 'infection thread,' which grows almost straight from the infected root-hair towards the vascular cylinder of the root, and a conical mass of cells develops which forms the young tubercle. Vascular strands are developed in the cortex of the tubercle, but there is no central strand of conducting tissue, and nothing comparable with a root-cap covering the end of the tubercle. In fully developed tubercles the 'bacteroid' tissue is situated entirely *within* the vascular strands—*intrafascicular*.

The root-tubercles of *Alnus, Elæagnus,* and *Cycas* are morphologically lateral roots, showing a central vascular cylinder, with a well-marked endodermis, completely surrounded by 'bacteroid' tissue—*extrafascicular*. These tubercles branch dichotomously, and are perennial, thus differing from leguminous tubercles, which are of limited growth.

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8. *Cell Division in* Merismopedia glauca. *By* B. H. BENTLEY.

Each cell is ovoid in form, with its long axis perpendicular to the surface of the colony. It contains a 'central body' which appears to consist of two spiral threads. During cell division each thread becomes wider and undergoes longitudinal fission. Two of the four threads pass into each daughter cell. No breaking of the threads into short segments was seen.

Section L.—EDUCATIONAL SCIENCE.

President of the Section—Sir Philip Magnus, B.Sc., M.P.

THURSDAY, AUGUST 1.

The President delivered the following Address:—

The Application of Scientific Method to Educational Problems.

Notwithstanding the fact that the greater part of my life has been spent in educational work, in teaching, in examining, in organisation, and in the investigation of foreign systems of instruction, I have experienced considerable difficulty in selecting, from the large number of subjects that crowd upon me, a suitable one on which to address you as President of a Section of the British Association devoted to educational science.

At the outset I am troubled by the title of the section over which I have the honour to preside. I cannot refrain from asking myself the question, Is there an educational Science, and if so, what is its scope and on what foundations does it rest? The object of the British Association is the advancement of Science, and year by year new facts are recorded in different branches of inquiry, on which fresh conclusions can be based. The progress of past years, whether in Chemistry, Physics or Biology, can be stated. Can the same be said, and in the same sense, of Education? It is true that the area of educational influence is being constantly extended. Schools of every type and grade are multiplied, but is there any corresponding advance in our knowledge of the principles that should govern and determine our educational efforts, or which can justify us in describing such knowledge as Science? If we take Science to mean, as commonly understood, organised knowledge, and if we are to test the claim of any body of facts and principles to be regarded as Science by the ability to predict, which the knowledge of those facts and principles confers, can we say that there exists an organised and orderly arrangement of educational truths, or that we can logically, by any causative sequence, connect training and character either in the individual or in the nation? Can we indicate, with any approach to certainty, the effects on either the one or the other of any particular scheme of education which may be provided? It is very doubtful whether we can say, that educational science is yet sufficiently advanced to satisfy these tests.

But although education may not yet fulfil all the conditions which justify its claim to be regarded as a science, we are able to affirm that the methods of science, applicable to investigations in other branches of knowledge, are equally applicable to the elucidation of educational problems. To have reached this position is to have made some progress. For we now see that if we are ever to succeed in arriving at fixed principles for guidance in determining the many difficult and intricate questions which arise in connection with the provision of a national system of education, or the solution of educational problems, we must proceed by the same methods of logical inquiry as we should adopt in investigating any other subject matter.

In order to bring Education within the range of subjects which should occupy a place in the work of this Association, our first efforts should be directed towards obtaining a sufficient body of information from all available sources, past and present, to afford data for the comparisons on which our conclusions may be based. One of the five articles of what is known as the Japanese Imperial Oath states, 'Knowledge shall be sought for throughout the whole world, so that the welfare of the Empire may be promoted'; and it may certainly be said that, as the welfare of our own Empire is largely dependent on educational progress, a wide knowledge of matters connected with Education is indispensable, if we are to make advances with any feeling of certainty that we are moving on the right lines.

There can be no doubt that of late years we have acquired a mass of valuable information on all sorts of educational questions. We are greatly indebted for much of our knowledge of what is being done in foreign countries to the Reports of different Commissions, and more particularly to those special reports issued from the Board of Education, first under the direction of my predecessor in this Chair, Professor Sadler, and latterly of his successor at the Board, Dr. Heath. But much of the information we have obtained is still awaiting the hand of the scientific worker to be properly co-ordinated and arranged. A careful collation of facts is indispensable if we are to deduce from them useful principles for our guidance, and unfortunately we in this country are too apt to rest content when we have provided the machinery for the acquisition of such facts without taking the necessary steps to compare, to co-ordinate, and to arrange them on some scientific principle for future use. Within the last week or two a Bill has passed through several stages in Parliament for requiring Local Authorities to undertake the medical inspection of school children, but, unless the medical inspectors throughout the country conduct their investigations on certain well considered lines laid down for them by some Central Authority, we shall fail to obtain the necessary data to enable us to associate educational and physical conditions with a view to the improvement of the training given in our schools.[1] On the other hand, although I personally am sceptical as to the results, we have reason to believe that the inquiry recently undertaken into the methods adopted here and elsewhere for securing ethical as distinct from specifically religious training will be so conducted as to give us not only facts, but the means of inferring from those facts certain trustworthy conclusions.

The consideration of Education as a subject capable of scientific investigation is complicated by the fact that it necessarily involves a relation—the relation of the child or adult to his surroundings. It cannot be adequately considered apart from that relation. We may make a study of the conditions of the physical, intellectual, and ethical development of the child, but the knowledge so obtained is only useful to the educator when considered in connection with his environment and future needs, and the means to be adopted to enable him, as he grows in physical, intellectual, and moral strength, to obtain a mastery over the things external to him. Education must be so directed as to prove the proposition that 'Knowledge is Power.' It can only be scientifically treated when so considered. Education is imperfectly described when regarded as the means of drawing out and strengthening a child's faculties. It is more than this. Any practical definition takes into consideration the social and economic conditions in which the child is being trained, and the means of developing his faculties with a view to the attainment of certain ends.

It is in Germany that this fact has received the highest recognition and the widest application, and for this reason we have been accustomed to look to that country for guidance in the organisation of our schools. We have looked to Germany because we perceived that some relation had been there established

[1] Since this was written the President of the Board of Education has stated in the House of Commons that 'it was the intention of the Board, if the Bill now before Parliament passed, to establish a medical bureau, which would guide and advise the local authorities as to the nature of the work they would have to do under the Act.'

between the teaching given to the people and their industrial and social needs; and further, that their success in commerce, in military and other pursuits was largely due to the training provided in their schools. Unmindful of the fact that Education is a relation, and that consequently the same system of education is not equally applicable to different conditions, there were many in this country who were only too ready to recommend the adoption of German methods in our own schools. Experience soon showed, however, that what may have been good for Germany did not apply to England, and that, in educational matters certainly, we do well to follow Emerson, who, when addressing his fellow citizens, declared: 'We will walk on our own feet; we will work with our own hands, and we will speak our own minds.' Still, the example of Germany and the detailed information which we have obtained as to her school organisation and methods of instruction have been serviceable to us.

Whilst all information on educational subjects is valuable, I am disposed to think that in our efforts to construct an educational science we may gain more by inquiring what has been effected in some of the newer countries. Wherever educational problems have been carefully considered and schemes have been introduced with the express intention and design of training citizens for the service of the State and of increasing knowledge with a view to such service, those schemes may be studied with advantage. Thus we may learn much from what is now being done in our Colonies. Their efforts are more in the nature of experiments. Our Colonies have been wise enough not to imitate too closely our own or any foreign system. They have started afresh, free from prejudice and traditions, and it is for this reason that I look forward with interest to the closer connection in educational matters of the Colonies with the mother country, and I believe that we shall gain much knowledge and valuable experience from the discussions of the Federal Conference which has recently been held in London, and which, I understand, is to be repeated a few years hence.

But valuable as are the facts, properly collated and systematically arranged, which a knowledge of British and foreign methods may afford us in dealing scientifically with any educational problem, it is essential that we should be able to test and to supplement the conclusions based on such knowledge, whenever it is possible, by direct experiments, applicable to the matter under investigation. We have not yet recognised the extent to which experiments in education, as in other branches of knowledge, may help in enabling us to build up an educational science. Some years since there was established in Brussels an *École modèle* in which educational experiments were tried. I visited the school in the year 1880, and I could easily point to many improvements in primary education which found their way from that school through the schools of Belgium and France to our own country, and, indeed, to other parts of the world. From a special Report on Schools in the North of Europe, recently published by the Board of Education, we learn that in Sweden the value of such experiments is fully recognised. We are told that in that country 'it was early felt that the uniformity in State Schools was of so strict a kind that some special provision should be made for carrying out educational experiments,' and experiments in many directions have been made, mainly in private schools, which receive, however, special subventions from the State. We gather from the same Report that the State regards the money as well earned 'if the school occasionally originates new methods from which the schools can derive profit.' I venture to think that experimental schools might with advantage be organised under the direction of some of our larger local authorities. The children would certainly not suffer by being made the subjects of such experiments. The intelligent teaching which they would receive—for it is only the most capable teachers who should be trusted with such experiments—would more than compensate for any diminution in the amount of knowledge which the children might acquire, and indeed such experimental schools might be conducted under conditions which would ensure sound instruction. Many improved methods of teaching are constantly advocated, but fail to be adopted because there is no opportunity of giving them a fair trial. As a general rule it is only by the effort of private individuals or associations that

changes in system are effected, and teachers are enabled to escape from the old grooves on to new lines of educational thought and practice. It is not difficult to refer to many successful experiments. The general introduction into our schools of manual training was the direct result of experiments carefully arranged and conducted by a Joint Committee of the City Guilds and the late London School Board. Experiments in the methods of teaching Physical Science, Chemistry, and Geometry have been tried, with results that have led to changes which have revolutionised the teaching of those subjects. The age at which the study of Latin should be commenced with a view to the general education of the scholar has been the subject of frequent trial. I would like to see such experiments more systematically organised, and I am quite certain that the curriculum of our rural and of our urban schools would soon undergo very considerable changes, if the suggestions of competent authorities could receive a fair trial under conditions that would leave no manner of doubt as to the character of the results.

It would seem, therefore, that if our knowledge of the facts and principles of education is not yet sufficiently organised to enable us to determine *a priori* the effect on individual or national character of any suggested changes, education is a subject that may be studied and improved by the application to it of scientific method, by accurate observation of what is going on around us, and by experiments thoughtfully conducted. This is the justification of the inclusion of the subject among those that occupy the attention of a separate section of this Association. Our aim here should be to apply to educational problems the well known canons of scientific inquiry; and, seeing that the conditions under which alone any investigation can be conducted are in themselves both numerous and complicated, it is essential that we should endeavour to liberate, as far as possible, the discussion of the subject from all political considerations. Such investigations are necessarily difficult. We have to determine both statically and dynamically the physical, mental, and moral condition of the child in relation to his activities and surroundings, and we have further to discover how he is influenced by them, how he can affect them, and the character of the training which will best enable him to utilise his experiences, and to add something to the knowledge of to-day for future service.

Notwithstanding the undoubted progress which we have made, it cannot be denied that in this country there still exists a large amount of educational unrest, of dissatisfaction with the results of our efforts during the last thirty years. This is partly due to the fact that there is much loose thinking and uninformed expression of opinion on educational questions. No one knows so little as not to believe that his own opinion is worth as much as another's on matters relating to the education of the people. In this way statements, the value of which has not been tested, pass current as ascertained knowledge, and very often ill-considered legislation follows. In this country, too, the difficulty of breaking away from ancient modes of thought is a great drawback to educational progress. Suggestions for moderate changes, which have been most carefully considered, are deferred and decried if they depart, to any great extent, from established custom, and the objection to change very often rests on no historical foundation. Occasionally, too, the change proposed is itself only a reversion to a previous practice, which was rudely broken by thoughtless and unscientific reformers. The opposition which was so long raised to the establishment of local universities was largely due to want of knowledge on the subject; and certainly the creation, some seventy years ago, of a teaching University in London was actually hindered through a mere prejudice, which broader views as to the real purposes of University teaching and fuller information on the course of University development would have removed.

There never was a time perhaps when it was more necessary than now that education should be regarded dispassionately, apart from political bias, as a matter of vital interest to the people as a whole. Education nowadays is a question which affects not only the life of a few privileged, selected persons, but of the entire body of citizens. The progress that has been made during the last few

years in nationalising our education has been very rapid. It may be that it has been too rapid, that sufficient thought has not been given to the altered social and industrial conditions which have to be considered. We have witnessed a strong desire and a successful effort to multiply Secondary and Technical Schools and to open more widely the portals of our Universities. The object of the desire is good in itself. As the people grow in knowledge the demand for higher education will increase; but the serious question to be considered is whether the kind of education which was supplied in schools, founded centuries ago to meet requirements very different from our own, is equally well adapted to the conditions which have arisen in a state of society having other needs and new ideals. Very rightly our students in training for the profession of teachers are expected to study the writings of Locke, Rousseau, Milton, Montaigne, and others; but many are apt to overlook the fact that these writers had in view a different kind of education from that in which modern teachers are engaged, and that their suggestions, excellent as many of them are, were mainly applicable to the instruction to be given by a tutor to his private pupil, and had little or no reference to the teaching of the children of the people in schools expressly organised for the education of the many. Only recently have we come to realise that a democratic system of education, a system intended to provide an intellectual and moral training for all citizens of the State, and so organised that, apart from any consideration of social position or pecuniary means, it affords facilities for the full development of capacity and skill wherever they may occur, must be essentially different in its aims and methods from that under which many of us now living have been trained. It has also been brought home to us that the marvellous changes in our environment, in the conditions under which we live and work, whether in the field, the factory, or the office, have necessitated corresponding changes in the education to be provided as a preparation for the several different pursuits in which the people generally are occupied. Yet, notwithstanding these great forces which have broken in upon and disturbed our former ideals, forces the strength and far-reaching effects of which we readily admit, we still hesitate to face the newly arisen circumstances and to adapt our educational work to its vastly extended area of operation and to the altered conditions and requirements of modern life.

When I say we hesitate to face the existing circumstances I do not wish to be misunderstood. As a fact changes are continually being discussed, and are from time to time introduced into our schools. But such modifications of our existing methods are generally isolated and detached, and have little reference to the more comprehensive measures of reform which are now needed to bring our teaching into closer relation with the changed conditions of existence consequent on the alterations that have taken place in our social life and surroundings.

Four years ago, it will be remembered, a committee of this section was appointed to consider and to report upon the 'Courses of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.' That committee, of which I had the honour to be chairman, presented a report to this section at the meeting of the Association held last year at York. The general conclusion at which they arrived was that 'the intellectual and moral training, and indeed to some extent the physical training, of boys and girls between the ages of seven and fourteen would be greatly improved if active and constructive work on the part of the children were largely substituted for ordinary class teaching, and if much of the present instruction were made to arise incidentally out of, and to be centred around, such work.' It is too early, perhaps, to expect that the suggestions made in that report should have borne fruit, but I refer to it because it illustrates the difference between the spasmodic reforms which from time to time are adopted, under pressure from bodies of well-meaning representatives of special interests, and the well-considered changes recommended by a committee of men and women of educational experience who have carefully tested the conclusions at which they have arrived.

There can be no doubt that, as regards our elementary education, there is very general dissatisfaction with its results, since it was first nationalised thirty-seven

years ago. Our merchants and manufacturers and employers of labour, our teachers in secondary and technical schools all join in the chorus of complaint. They tell us that the children have gained very little useful knowledge and still less power of applying it. There is enough in this general expression of discontent to give us pause and to make us seek for a rational explanation of our comparative failure. The inadequacy of the results attained to the money and effort that have been expended is in no way due to any want of zeal or ability on the part of the teachers, or of energy on the part of school boards or local authorities. They have all discharged the duties which were imposed upon them. It is due rather to the fact that the problem has been imperfectly understood, that our controlling authorities have had only a vague and indistinct idea of the aim and end of the important work which they were charged to administer. If we look back upon the history of elementary education in this country since 1870, we cannot fail to realise how much its progress has been retarded by errors of administration due very largely to the want of scientific method in its direction. It is painful to reflect, for instance, on the waste of time and effort, and on the false impressions produced as to the real aim and end of education, owing to the system of payment on results, which dominated for so many years a large part of our educational system. We must remember that it is only within the last few decades that education has been brought within reach of all classes of the population. Previously it was for the few; for those who could pay high fees; for those who were training for professional life, whether for the Church, the Army, the Navy, Law, or Medicine, or for the higher duties of citizen life. This had been the case for centuries, not only in this country but in nearly all parts of the civilised world. If we read the history of education in ancient Greece or Rome, or mediæval Europe, we shall see that popular education, as now understood, was unknown. All that was written about education applied to the few who got it, and not to the great mass of the people engaged in pursuits altogether apart from those in which the privileged classes were employed. Trade and manual work were despised, and were considered degrading and unworthy of the dignity of a gentleman. I need scarcely say that these social ideas are no longer held. The fabric of society is changed, and we have to ask ourselves whether the methods of education have been similarly changed, whether they have been wisely and carefully adapted to the new order of things. What is it that has really happened? Is it not true that we have annexed the methods and subjects of teaching which had been employed during many centuries in the training of the few and applied them to the education of the people as a whole—to those who are engaged in the very callings which were more or less contemned? Surely it is so, and the results are all too manifest. We have applied the principles and methods of the secondary education of the Middle Ages to our new wants, to the training of the people for other duties than those to which such education was considered applicable, and it is only within the last few years that we have begun to see the error of our ways. In the report of your committee, to which I have referred, it is pointed out that the problem of primary education has been complicated by the introduction of the methods which for many years prevailed in secondary schools, and at a meeting of the National Education Association, held only a few weeks since, it was truly said: 'In this country secondary education preceded primary by several centuries, and so the nation now finds itself with the aristocratic cart attempting to draw the democratic horse.'

Let it not be supposed that in the days not so far distant, yet stretching back into the remote past, the people as a whole were uneducated. This was not so. But we have to widen the meaning of education to include the special training which the people then received—an education that was acquired without even the use of books. It cannot for one moment be said that the artisans, the mechanics, the farm hands, male and female, were wholly uneducated in those far-off days. In one sense possibly they were. Very few of them could read or write. But from earliest childhood they had received a kind of training the want of which their descendants have sadly felt in the cloistered seclusion of the modern elementary school. They were brought face to face with Nature. They learned

the practical lessons of experience; and as they grew up their trade apprenticeship was an education which we have been trying vainly to reproduce. They gained some knowledge of the arts and sciences, as then understood, underlying their work. Their contact with their surroundings made them thoughtful and resourceful, for Nature is the most exacting and merciless of teachers. The difficulties they had to overcome compelled them to think, and of all occupations none is more difficult. They were constantly putting forth energy, adapting means to ends, and engaging in practical research. In the field, in the workshop, and in their own homes boys and girls acquired knowledge by personal experience. Their outlook was broad. They learned by doing. It is true that nearly all their occupations were manual, but Emerson has told us, 'Manual labour is the study of the external world.'

Compare for a moment this training with that provided in a public elementary school, and you cannot be surprised to find that our artificial teaching has failed in its results, that our young people have gained very little practical knowledge, and that what they have gained they are unable to apply; that they lack initiative and too often the ability to use books for their own guidance, or the desire to read for self-improvement. We seem to have erred in neglecting to utilise practical pursuits as the basis of education, and in failing to build upon them and to evolve from them the mental discipline and knowledge that would have proved valuable to the child in any subsequent occupation or as a basis for future attainments. We have made the mistake of arresting, by means of an artificial literary training, the spontaneous development of activity, which begins in earliest infancy and continues to strengthen as the child is brought into ever closer contact with his natural surroundings. We have provided an education for our boys which might have been suitable for clerks; and, what is worse, we have gone some way, although we have happily cried a halt, to make our girls into 'ladies,' and we have run some risk of failing to produce women.

If we are to correct the errors into which we have drifted, if we are to avert the consequences that must overtake us through having equipped our children for their life-struggle with implements unfitted for their use, we must consider afresh the fundamental ideas on which a system of elementary education should be based. Instead of excluding the child from contact with the outer world we must bring him into close relationship with his surroundings. It was given to man to have dominion over all other created things, but he must first know them. It is in early years that such knowledge is most rapidly acquired, and it is in gaining it that the child's intellectual activities are most surely quickened.

It is unfortunate that we failed to realise this great function of Elementary Education when we first essayed to construct for ourselves a national system. The three R's, and much more than that, are essential and incidental parts of Elementary Education. But what is needed is a *Leitmotif*—a fundamental idea underlying all our efforts and dominating all our practice, and I venture to think that that idea is found in basing our primary education on practical pursuits, on the knowledge gained from actual things, whether in the Field, the Workshop, or the Home.

Instead of fetching our ideas as to the training to be given in the people's schools from that provided in our old grammar schools, we should look to the occupations in which the great mass of the population of all countries are necessarily engaged, and endeavour to construct thereon a system with all such additions and improvements as may be needed to adapt it to the varied requirements of modern life. By this process—one of simple evolution adjusted to everyday needs—a national system of education might be built up fitted for the nation as a whole—a system founded on ideas very different from those which, through many centuries, have governed the teaching in our schools. In the practical pursuits connected with the Field, the Workshop, and the Home, and in the elementary teaching of science and letters incidental thereto, we might lay the foundation of a rational system of primary education.

These three objects—the Field, the Workshop, and the Home—should be the pivots on which the scheme of instruction should be fixed, the central

thoughts determining the character of the teaching to be given in rural and urban schools for boys and girls. It was Herbart who insisted on the importance of creating a sort of centre around which school studies should be grouped with a view to giving unity and interest to the subjects of instruction. I have elsewhere shown how a complete system of primary education may be evolved from the practical lessons to be learned in connection with outdoor pursuits, with workshop exercises and with the domestic arts, and how, by means of such lessons, the child's interest may be excited and maintained in the ordinary subjects of school instruction, in English, arithmetic, elementary science, and drawing. In the proposals I am now advocating I am not suggesting any narrow or restricted curriculum. On the contrary, I believe that, by widening the child's outlook, by closely associating school work with familiar objects, you will accelerate his mental development and quicken his power of acquiring knowledge. I would strongly urge, however, that the child should receive less formal teaching, that opportunities for self-instruction, through outdoor pursuits, or manual exercises, or the free use of books, should be increased, so that as far as possible the teacher should keep in view the process by which in infancy and in early life the child's intelligence is so rapidly and marvellously stimulated. Already we have discovered that our unscientific attitude towards primary education has caused us to overlook the essential difference between the requirements of country and of town life, and the training proper to boys and girls. Our mechanical methods of instruction, as laid down in codes, make for uniformity rather than diversity, and we are only now endeavouring, by piecemeal changes, to bring our teaching somewhat more closely into relation with existing needs. But the inherent defect of our system is that we have started at the wrong end, and, instead of evolving our teaching from the things with which the child is already familiar, and in which he is likely to find his life's work, we have taken him away from those surroundings and placed him in strange and artificial conditions, in which his education seems to have no necessary connection with the realities of life.

The problem of primary education is to teach by practical methods the elements of letters and of science, the art of accurate expression, the ability to think and to control the will; and the ordinary school lessons should be such as lead to the clear apprehension of the processes that bring the child into intimate relation with the world in which he moves. During the last few years the importance of such teaching has dimly dawned upon our educational authorities, but, instead of being regarded as essential, it has been treated as a sort of *extra* to be added to a literary curriculum, already overcrowded. What is known as manual training is to some extent encouraged in our schools, but it forms no part of the child's continuous education. It is still hampered with conditions inconsistent with its proper place in the curriculum, and is uncoordinated with other subjects of instruction. Moreover no connecting link has yet been forged between the teaching of the Kindergarten and workshop practice in the school. We speak of lessons in manual training as something apart from the school instruction, as something outside the school course, on the teaching of which special grants are paid. Twenty or thirty years ago people used to talk about 'teaching technical education,' and from this unscientific way of treating the close connection that should exist between hand-work and brain-work our authorities have not yet freed themselves.

It is true we have long since passed that stage when it was thought that the object of instruction in the use of tools was to make carpenters or joiners; but, judging from a report recently issued by the Board of Education, it would seem that it is still thought that the object of cookery lessons to children of twelve to fourteen years of age is the training of professional cooks. Until the Board's inspectors can be brought to realise that the aim and purpose of practical instruction in primary schools, whether in cookery or in other subjects, is to train the intelligence through familiar occupations, to show how scientific method may be usefully applied in ordinary pursuits, and how valuable manipulative skill may thus be incidentally acquired, it does not seem to me that they themselves have

learned the most elementary principles of their own profession. An anonymous teacher, writing some weeks since in the 'Morning Post,' said: 'The cookery class can be made an invaluable mental and moral training ground for the pupils, the most stimulating part of primary education. It teaches unforgettable lessons of cleanliness and order, of quickness and deftness of movements. The use of the weights and scales demands accuracy and carefulness, and the raw materials punish slovenliness or want of attention with a thoroughness which the most severe of schoolmasters might hesitate to use. Practical lessons in chemistry should form an important feature of each class. . . . The action of heat and moisture on grains of rice provides an interesting lesson on the bursting of starch cells, and the children's imagination is awakened by watching the hard isolated atoms floating in milk change slowly to the creamy softness of a properly made rice pudding. The miraculous change in the oily white of egg when it is beaten into a mountain of snowy whiteness gives them interest in the action of air and its use in cookery.'

Can the teaching of grammar or the analysis of sentences provide lessons of equal value in quickening the intelligence of young children?

I must add one word before passing from this suggestive illustration of the value of scientific method in the treatment of educational questions. We live in a democratic age, and any proposed reform in the teaching of our primary schools must be tested by the requirement that the revised curriculum shall be such as will provide not only the most suitable preparatory training for the occupations in which four-fifths of the children will be subsequently engaged, but will, at the same time, enable them or some of them to pass without any breach of continuity from the primary to the secondary school. There mast be no class distinctions separating the public elementary from the State-aided secondary school. The reform I have suggested is unaffected by such criticism. The practical training I have advocated, whether founded on object lessons furnished by the Field, the Workshop, or the Home, would prove the most suitable for developing the child's intelligence and aptitudes and for enabling him to derive the utmost advantage from attendance at any one of the different types of secondary schools best fitted for his ascertained abilities and knowledge. The bent of the child's intellect would be fully determined before the age when the earliest specialisation would be desirable. No scheme of instruction for primary schools can be regarded as satisfactory, which is not so arranged that, whilst providing the most suitable teaching for children who perforce must enter some wage-earning pursuit at the age of fourteen, or at the close of their elementary school course, shall at the same time afford a sound and satisfactory basis on which secondary and higher education may be built. And I hold the opinion, in which I am sure all teachers will concur, that a scheme of primary education pervaded by the spirit of the Kindergarten which, by practical exercises, encourages observation and develops the reasoning faculties, and creates in the pupil an understanding of the use of books, would form a fitting foundation for either a literary or a scientific training in a secondary school.

I have purposely chosen to illustrate the main subject of this address by reference to defects in our primary instruction, because the success of our entire system of education will be found, year by year, to depend more and more upon the results of the training given in our public elementary schools. We have scarcely yet begun to realise the social and political effects of the momentous changes in our national life, consequent on the first steps which were taken less than forty years ago to provide full facilities under State control and local management for the education of the people.

At present all sorts of ideas are afloat which have to be carefully and scientifically considered. The working classes have to be further and somewhat differently educated, in order that they may better understand their own wants and how they are to be satisfied. We have placed vast powers in the hands of local bodies, popularly elected, powers not only of administration, for which they are well adapted, but powers of determining to a very great extent, by the free use of the rates, the kind of instruction to be given in our schools, and the

qualifications of the teachers to impart it. Moreover, these local bodies have shown, in many instances, a distrust of expert advice and a desire to act independently as elected representatives of the people, which cannot fail for some time at least to lead to waste of effort and of means. It was said years ago, when the centre of our political forces received a marked displacement, that we must educate our masters. Our masters now, both in politics and education, are the people, and it is only, I believe, by improving their education that we can enable them to understand the essential difficulties of the problems which they are expected to solve, and can induce them to rely, to a greater extent than they do at present, on the results of the application to such problems of scientific method, founded on the fullest information obtainable from historical and contemporary sources.

I might have illustrated my subject by reference to the acknowledged chaotic condition of our secondary education. In the report of the Board of Education published in December last we read: 'While the development of secondary education is the most important question of the present day, and is the pivot of the whole education as it affects the efficiency, intelligence, and well-being of the nation, yet its present position may be described as "chaos."' The 'chaos' by which the present position of our secondary education is here described is intimately connected with the questions relating to primary education, which I have been engaged in considering. If we construct a system of primary education which serves equally for children of all classes, apart from social conditions—a system educationally sound, both as a preparation for immediate wage-earning pursuits and for more advanced and somewhat more specialised training in a secondary school, many of the difficulties which confront the Board of Education, and which are largely of an administrative order, would disappear. The difficulties are in part dependent on the question of curriculum, to the discussion of which a day will be devoted during the present meeting.

University education in this country, and indeed in other countries, has also suffered much from the hands of the unscientific reformer. In Germany, owing to many causes, the higher education has made considerable advances during the past century; but, even in that country, a more critical study of the development of University education and a truer recognition of the twofold function of a University might have prevented the early separation in distinct institutions and under separate regulations of the higher technical from University instruction. Only within recent years has France retraced her steps and returned to the University ideal of seven centuries ago. But perhaps the climax of unscientific thinking was reached in the scheme, happily abandoned, of founding a new University in Dublin on the lines suggested by Mr. Bryce in his now famous speech of January last.

Our conception of the functions of a University has undergone many violen changes. Between the ideal of the University of London prior to its reorganisation and that of a mediæval University, in which students were never plucked, obtaining their degrees whether they did their work well or badly, there have been many variations; but I think it may be said that, recently at any rate, we have come to realise the fact that our Universities, to fulfil their great purpose, must be schools for the preparation of students for the discharge of the higher duties of citizenship and professional life, and Institutions for the prosecution of research, with a view to the promotion of learning in all its branches, and that examinations for degrees, necessary, as they undoubtedly are, as tests of the extent of a student's acquired knowledge, must be regarded as subordinate to these two great functions.

I will not detain you longer. I have endeavoured to show under what limitations education may lay claim to be included among the sciences, and how a knowledge of the history of education and the application of the methods of scientific inquiry may help in enabling us to solve many of the intricate and complicated questions which are involved in the establishment on a firm foundation of a national system of education. I have taken my illustrations mainly from the reform of elementary, or, as I prefer to call it, primary education, and

I have sought to indicate some of the errors into which we may fall when we fail to apply to the consideration of the problem the same principles of inductive inquiry as are employed in all investigations for the attainment of Truth.

I believe that this Section of the British Association has the opportunity of rendering a great service to the State. Numerous educational societies exist, in which questions of importance are discussed, and all, perhaps, do useful work. But none is so detached from separate and special interests; none stands so essentially apart from all political considerations; none is so competent to discuss educational problems from the purely scientific standpoint as are the members of this Association. If, in the remarks I have offered, somewhat hastily prepared under the pressure of many different kinds of work, I have contributed anything to the solution of a problem, the difficulty and national importance of which all will admit, I shall feel that I have not been altogether unworthy of the honour of occupying this Chair.

The following Reports and Papers were then read:—

Joint Discussion with Section H on Anthropometrics in Schools.

1. (i) *Report on Anthropometric Investigation in the British Isles.*
See Reports, p. 354.

(ii) *Anthropometrics in Schools. By* J. Gray, *B.Sc.*

Measurements and observations in all schools should be made in accordance with the scheme of the Anthropometric Committee of the British Association. The data obtained should be entered on the card schedules recommended by the said Committee.

The front card contains data concerning the stock to which the subject belongs, including such information as insurance companies demand from their clients—namely, the age, or age at death, of parents and grandparents, brothers and sisters, and first cousins, the size of family and position of subject in it, the nature and frequency of family complaints, such as gout and heart or lung disease. This information is most conveniently given by reference to the schedules of the relatives, where such exist.

The following cards contain data as to the physical and mental characters, ealth and environment of the subject. In the case of a child, these data are tered on separate cards for each year of its school life.

If data can be obtained after the subject leaves school, cards with these should e added to the subject's *dossier*.

All these data, for each individual, having been entered upon cards, which are kept together, as forming a more or less complete record of his structure, activities, defects or disease, and of the factors of his environment, we have the material for ascertaining with the greatest possible accuracy the nature of the human machine, and how it is controlled by changing the environment.

This is done by calculating correlations between any pair of characters whose values are recorded.

We have reason to believe that correlations of greater or less intensity exist between all the characters of man and the factors of his environment. Very few have as yet been calculated on account of the lack of data, and in many cases where they have been calculated the values obtained are untrustworthy, because the methods of observation have not been sufficiently precise. One of the great benefits to be derived from the general introduction of anthropometry in schools would be the supply of data for the calculation of a large number of useful correlations, which would point the way for legislative and other measures of reform. For example, the effect of free meals to school children on their physical and mental characters might be predicted; or the ultimate effect of the increasing

urbanisation of our population on the character of the nation. The following are some correlations that have been ascertained with more or less accuracy:—

Pigmentation and	Habitat (urban and rural).
	Disease.
	Mental and moral characters.
Intelligence	Over- and under-feeding.
Social status	Physical and mental characters.
Dentition	Nutrition.

(iii) *The Aims and Function of Anthropometry in relation to the School. By* F. C. Shrubsall, *M.A., M.D.*

Anthropometrics covers everything in the structure and functions of the human body susceptible of definite measurement.

The exactness of the data and ease of interpretation vary. To obtain valuable results exact conditions of experiment are necessary to reduce the number of variable factors at any given time.

By means of correlations it is possible to determine the mutual changes in pairs of factors under the influence of some common cause.

While the most reliable evidence is obtained as to physique, data can also be obtained for fatigue and for some mental processes.

The chief need at present is to establish a series of norms and the allowable range of variation. Work in this direction has recently been done in the schools in London, Liverpool, Bradford, Dunfermline, and elsewhere.

The value of food-supplies, surroundings, hours of sleep, &c., of children is being gradually determined, and it is probable that light will be thrown on the problems of the best forms of exercise for school children under different conditions, and possibly even on the arrangement of the curriculum. For these purposes considerable numbers of observations will be necessary, and these must have been made under practically uniform conditions.

(iv) *On the Practical Difficulties in obtaining Measurements of Growth in Schoolboys.*[1] *By* E. Meyrick, *B.A., F.R.S.*

Although the task of obtaining regular measurements of growth in schoolboys seems at first sight a simple one, the paucity of such measurements shows that in practice considerable difficulties are met with.

These are partly (1) essential, arising from such causes as the smallness of the differences to be apprehended, or the troublesome nature of some tests, which require practice in the boy tested; but more particularly (2) circumstantial, especially (*a*) causes of irregularity, such as illness, indolence or indifference, and preoccupation, and (*b*) causes of inaccuracy, such as inexpertness of operator, uncertainty of dates or age, variation of clothing or other conditions, and uneven or spasmodic rate of growth. These perturbations are so considerable that the final results would be nearly valueless unless available in bulk, when they are automatically corrected by the law of average. Some figures were given to show that, notwithstanding these difficulties, consistent results are obtainable.

2. *Report on the Conditions of Health essential to the carrying-on of the Work of Instruction in Schools.*—See Reports, p. 421.

3. *Types of Physical Development in Schools. By* Cecil Hawkins, *M.A.*

What the schoolmaster requires from a system of physical measurements is an easy means of discovering whether individuals or groups of individuals are thriving or the reverse.

[1] Published in the *School World* for September 1907.

A good rough estimate of the manner in which a boy is thriving can be formed by comparison of periodic measurements of his height and weight. In order that the lesson to be learnt from these observations may be sufficiently obvious a system of grades is required. Comparison with the rate of growth of the mean boy is unsatisfactory; a high-grade boy of fourteen will normally grow twice as fast as a low-grade boy, while at eighteen the low-grade boy should be growing twice as fast as the high-grade boy.

I have used for some years a set of tables by means of which the height and weight of all boys observed may be referred to one or other of twenty grades—all equally probable—of which grade 1 is the highest. The record of a boy's growth can conveniently be kept upon a form divided by parallel lines into twenty spaces to represent the twenty grades, separate graphs being drawn for height and weight. These graphs will be fairly level in rather more than 50 per cent. of the cases observed. In the majority of the remaining cases periods of steady rise or fall will be noted in which the two graphs, as a rule, remain fairly parallel. In some cases the graphs are very irregular, constant fluctuations being apparent. In such cases the fluctuations in the two graphs are generally found to correspond.

Consecutive observations will give the same grade in about 50 per cent. of the cases observed. The graph normally rises in 25 per cent. and falls in 25 per cent., speaking roughly. Any disturbing cause will alter these proportions in a group affected by it; *e.g.*, in a school in which observations are recorded in March, June, and October or November I found that in the various intervals the percentages

In Height.	Up	Level	Down
March to June	25·4	53·0	21·6
June to October	33·1	45·7	21·2
November to March	14·2	47·3	38·6

In Weight	Up	Level	Down
March to June	33·5	41·2	25·4
June to October	35·9	41·6	22·7
November to March	24·4	37·6	38·0

Variations in chest-girth are far more marked than those in height and weight, the chief disturbing factor being systematic physical training. Thus of 225 Haileybury boys—taken as they came—who were measured on entrance, and again after three terms of compulsory physical training, one boy improved 15 grades in chest-girth, three boys 13 grades, four boys 12 grades; 12 per cent. had gone down from 1 to 5 grades, 14 per cent. were level, 50 per cent. had improved from 1 to 5 grades, 15·5 per cent. from 5 to 10 grades, and 8·5 per cent. had improved more than 10 grades.

Typical schemes of development may be arrived at by working out the average grades of the type required. E.g., *Typical Athletes* grade at 7 in height, 5 in chest-girth, 3 in weight, and are early developed. *Typical Gymnasts* grade 13 in height, 7 in weight and chest-girth, the grade of height being very uniform throughout their scheme of growth. *Typical Scholars* grade 9 in height and chest-girth, 7 in weight. The importance of weight as a sign or factor of vigour is very marked.

For general use I would urge that a system of percentile grades be adopted, which should include all classes of the population. In order to construct such a system we require a large number of accurate observations, which must include children of all ages, subject to every variety of condition as regards nurture and environment.

FRIDAY, AUGUST 2.

The following Papers were read:—

1. *The English Scholarship System: its Principles and Results. By* Professor M. E. Sadler, *LL.D., and* H. Bompas Smith, *M.A.*

The paper of which this is a summary is the outcome of an inquiry conducted by the authors in different parts of England during the summer of 1907, with the help of officers of local education authorities and of headmasters, headmistresses, and other teachers in elementary and secondary schools.

The scholarship system is a distinctive mark of English education. Its beginnings date from the Middle Ages. Its modern developments are connected with the growth of competitive examinations, upon which it largely depends. There has always been in England a readiness to help forward youths of exceptional promise to intellectual opportunities appropriate to their powers. But there has also been a great reluctance to place secondary and higher education under the direct control of the State, and consequently a preference for a variety of semi-independent schools representing different social traditions and points of view. These two facts in combination resulted in the scholarship system, to which in the mid-Victorian era the general belief in the benefit of open competition gave a wider vogue. During the last generation, however, new forces have subjected English educational arrangements to a heavy strain. Improved higher education had become on civic and economic grounds a national necessity. New sections of the community were demanding access to secondary schools. It became necessary, therefore, either to extend the scholarship system or to embark upon a policy of free, or nearly free, secondary and higher education in institutions under direct public control. The latter policy would have been wasteful of existing educational resources. Nor is the remission of school fees sufficient by itself to enable the poorest scholars to postpone the time of their entrance into wage-earning occupations. Maintenance allowances are also necessary. The scholarship policy has enabled the local authorities established under the Education Act of 1902 to meet in the quickest and most economical manner the demand for extended facilities for secondary education, a demand accelerated by new Government regulations for the training of pupil-teachers. The fact that many of their pupils pay fees has enabled the secondary schools to carry on their work with less public aid than would otherwise have been necessary, and more public money has thus been made available for maintenance allowances. Thus through the rapid extension of the scholarship system, which links together schools of different types under the general supervision of public authority, much has been done within the last five years to construct a framework of national education.

The five chief branches of the English scholarship system are: (1) Scholarships tenable at universities or other places of advanced education; (2) scholarships tenable at the great secondary boarding-schools ('Public Schools'); (3) junior scholarships from the public elementary schools to the secondary day schools; (4) intermediate scholarships enabling pupils to prolong their secondary education; (5) scholarships tenable at evening schools and classes.

The new regulations for the payment of Government grants to secondary schools may greatly affect the present situation. But the scholarship system has at any rate served as a useful expedient in a time of rapid social change. There is some reason to think that the offer of junior scholarships has been too profuse. Improvements in the elementary and secondary schools themselves are far more important than an indefinite increase of facilities for the transference of children from the one to the other.

The following have been the chief results of the working of the scholarship system as it has developed in England during recent years:—

(1) The scholarship system has made the English universities, old and new, the educational goal of hundreds of students of good ability who under former conditions would have been shut out from academic studies.

(2) Many boys and some girls of exceptional ability have been helped forward to high academic distinction.

(3) A large number of boys and girls from public elementary schools have been enabled by means of scholarships to obtain access to secondary schools. This has been especially the case during the last five years, in consequence of the operation of the Education Act, 1902, and the requirements of the new regulations for the training of pupil-teachers.

(4) In some cases the provision of junior scholarships of small value has been in excess of the needs of the situation. With this has occasionally gone a tendency to fail in giving sufficiently prolonged or ample help to the handful of pupils who show very marked ability or promise. To secure for large numbers of children of average powers a somewhat longer education than they would otherwise have received is an excellent object, if the education so given is appropriate to the children's needs. But a scholarship system may in the long run prove socially deleterious if it gives brief but widespread encouragement to merely average ability without at the same time taking special pains to secure the opportunity of long and thorough training for carefully selected individuals of unusual capacity. And a scholarship system is economically vicious if it imposes a disproportionate share of the burden of taxation upon cultivated families with slender incomes without at the same time providing for such families educational opportunities of an intellectual quality appropriate to their needs.

(5) To a limited extent scholarships have bridged over the gulf between lower and higher secondary education, a gulf which in England is social as well as intellectual.

(6) The scholarship system has virtually failed to span the gap between the public elementary schools and the great Public (boarding) Schools. The latter are mainly fed from a special type of preparatory school. But many clever boys whose parents can give them the intellectual preparation afforded by such preparatory schools are enabled by scholarships to obtain a Public School education at a greatly reduced cost. And it appears that, in the majority of cases, these boys could not be sent to Public Schools of this kind without such pecuniary help.

(7) A lopsided development has recently been given to the scholarship system through the administrative need of securing large numbers of recruits (chiefly girls) for the elementary school teaching profession. Apart from this, the claims of girls are still less liberally recognised than those of boys.

(8) The records kept of the later careers of scholarship-holders are at present inadequate. Such evidence as is forthcoming points to the conclusion that an overwhelming majority pass into literary, clerical, and other non-industrial callings. This would suggest that the scholarship system as at present organised fails to select and reward a due proportion of boys and girls whose abilities are practical and constructive rather than literary or purely scientific.

(9) A chief motive in the English scholarship system has been the benevolent desire to give every clever boy (and, more recently, clever girls) a chance of individual advancement through higher education. But less thought seems to have been given to the practical question, What kind of secondary and higher education is best suited to the special aptitudes of each individual scholarship-winner? As the dominant tradition in the older form of secondary education for boys has been fixed by the requirements of literary callings, many of the secondary schools which are justly held in high esteem are not necessarily in a position to give the most suitable training to all the pupils for whom a slightly prolonged education is now desired. The experience gained through the working of the present scholarship system is revealing the lack of adjustment between some traditional courses of study and the intellectual and social needs of modern life. To remedy this defect new types of secondary school curriculum are needed.

(10) The scholarship question should be looked at from a national point of view, not only from the standpoint of the personal advantage and preferment of the individual scholar. The fundamental purpose of a scholarship system in all its grades and branches is the direction of ability towards those callings in which the individual scholars are best qualified, by natural aptitude and by physical

stamina to render valuable service to the nation. But hitherto there has been some tendency to give preferential treatment to the recruiting of the more literary professions.

(11) The English scholarship system has worked fairly well in a rough sort of way during a period of rapid social change and of resulting educational development. But in itself it is no sufficient substitute for a coherent system of higher education, intellectually efficient in all its grades and practically adjusted to the needs of a modern community.

Reforms needed.

(i) Our fundamental needs are the reform of the elementary schools, both in town and country, and the provision of new types of secondary school curriculum. The conditions under which the vast majority of English elementary school teachers are at present obliged to work prevent them from giving a sufficiently individualised training, moral and intellectual, to the children committed to their care. The improvement of the elementary school will secure for the children the kind of early training which will best enable the more promising of them to take advantage of advanced courses of study. It will also tend to lessen the social cleavage which at present destroys the unity of English education in its elementary stage. But any effective improvement will be very costly, and necessarily slow in operation. The necessary counterpart of the reform of the elementary school will be the increased differentiation of the secondary schools and the better adaptation of their curricula to modern needs. Nearly all the secondary day schools in England need more generous financial assistance in order to attain a new measure of intellectual efficiency.

(ii) The English scholarship system in its present form gives special advantage to urban districts. It fails adequately to meet the needs of promising children living in the country. These are often prevented by distance or expense from gaining access to a secondary school. In some cases more boarding scholarships are needed. Secondary 'tops' should be added to some centrally situated rural elementary schools.

(iii) Much more should be done to provide higher secondary education of first-rate quality in day schools in many smaller towns. There is a danger of higher secondary education becoming (outside a few favoured centres) the privilege of the well-to-do. The new Regulations for Secondary Schools increase this danger. Government grants at a considerably higher rate are needed for higher secondary schools and in aid of higher secondary 'tops' in other carefully selected secondary schools.

(iv) There is need for a more generous provision of intermediate and higher scholarships to enable pupils of special ability to complete the full course at a higher secondary school or to proceed to an institution of university rank or of advanced professional training. For girls especially more higher scholarships are required, tenable at a variety of institutions for academic or practical study.

(v) The fixed value of the scholarships awarded by open competition at the Public Schools and Universities might well be reduced. Ample supplementary allowances should be given to those scholars who need them, after private inquiry into the circumstances of each case.

(vi) Methods of selection which set a premium upon cramming and lead to the neglect of the candidate's health and physique should be sternly discouraged. The best examinations now conducted for junior scholarships are confined, so far as written tests are concerned, to papers in English and arithmetic. The written examination should, where numbers are not too great, be supplemented by a simple oral test. The examiners should also have access to the pupil's school record. Stress should always be laid upon physical fitness. Each local scholarship system might thus become an incentive to the healthy up-bringing of children by making a fair standard of physical development a condition of eligibility.

2. *Scholarships for Girls from Elementary to Secondary Schools.* *By* Isabel Cleghorn, *L.L.A.*

In directing attention to existing scholarship schemes it is well to ask whether they are always of the right kind, awarded to the right children, in the right manner, and leading in the right direction.

The true purpose of any scholarship system should be to give children of special ability the opportunity of continuing their education on the best possible lines. As, in ordinary circumstances, the poorer parents are unable to keep their children at school beyond the age when they may reasonably expect them to begin to add to the family income, it is necessary that there should be a full and complete system of maintenance scholarships, so that specially gifted children from the elementary schools should have every possible chance of developing all that is in them for the good of the community at large. With regard to scholarships for girls, differentiation must be made between two kinds; the one generally known and fairly freely given already, the other scarcely as yet recognised as necessary, but in reality equal, if not superior, in importance, for the future well-being of the social and industrial side of our life as a nation.

I. Those of the literary type leading from the elementary school proper to the higher elementary, the municipal secondary, the grammar or high school or the pupil-teacher centre.

Such scholarships are fairly numerous but very unequally distributed. Many of them are earmarked for the teaching profession—a system to be deprecated—and many of them are scholarships only, prohibitive to the children of the labouring classes, who find themselves unable to provide the necessary maintenance while the scholarship lasts.

But besides the necessity for providing a liberal number of maintenance scholarships for the intellectually endowed children from our elementary schools, it is also essential that the 'corridor' from the one school to the other should not only be widely open, but that the curricula of the two schools should be so co-ordinated that the one should form the natural entrance to the other, and the names 'primary' and 'secondary' be realities and not unmeaning titles. Such scholarships should not be awarded on written examinations only, but depend also on the recommendation of the primary teacher and in some cases on a joint oral examination conducted by the head teachers of both the elementary and secondary schools.

II. Practical scholarships leading girls from the elementary school to some form of domestic or industrial training.

These should never be awarded on a written examination. They should depend, not on the power to write well, spell correctly, and describe clearly in accurate English, but should be bestowed on the girl of faculty, the bright, intelligent, but not especially intellectual, girl whose senses are alert, who has the true eye, the delicate touch, the power to *do*.

It is quite as necessary to prepare the future wife and mother for the duties of home making, the future workwoman for the labour of the workshop, the future servant for the routine of the kitchen, as it is to help the future teacher to obtain the knowledge to enable her to fulfil the duties of the schoolroom.

All work is sacred, and true education helps people to live their lives so as to get and to give the greatest possible amount of good.

Education that carries children forward into their future work in the world, be it brain-work or work with the hands, is 'secondary,' and therefore equal facilities should be given to both. Up to the present, only London, a few of our large provincial cities, such as Gloucester and Bradford, and two or three philanthropic firms, such as Rowntree's of York and Cadbury's of Bournville, have seriously undertaken the provision of this kind of secondary education. In London the polytechnics, the technical institutes, and trade schools are doing magnificent work, while many of the elementary schools possess cookery, laundry, and housewifery centres where really good practical teaching is given.

To the polytechnics and technical institutes some three or four hundred

L.C.C. maintenance scholarships are given annually, by means of which girls from the elementary schools receive twelve months' instruction in domestic subjects, while some eighty additional scholarships, awarded on special aptitude, carry forward the best of these girls into the trade schools, where under skilful and competent teachers they specialise in such work as dressmaking, corset or waistcoat making, upholstery, tailoring, or art needlework.

The spread of such secondary education is one of the necessities of modern times, and when this is fully recognised by education authorities throughout the country a liberal supply of scholarships for the same should follow as a matter of course.

3. *The Scholarship System.* *By* A. R. Pickles, *M.A.*, *B.A.*

a. School Relationships.—In view of the rapid increase of municipal secondary schools and of the modernising of many of the older foundations, and especially in view of the most recent pronouncements of the Board of Education in favour of a broadly democratic scheme of higher education, it is of importance to define the precise relationship between the primary and the secondary school systems, in order to be able to discuss a scholarship system with any real profit.

b. The Aim of the Primary School.—The old conception of the primary school as a place for teaching poor children the three R's, along with a smattering of history and geography, has happily receded, giving place to the new conception, which regards these schools as places for the formation of right habits, for the cultivation of thought and intelligence, and for fashioning the tools of learning. To regard a child's education as completed at the close of the primary school period is an absurdity. He may, by imitation, by the aid of a retentive memory, and by an oftentimes puzzling inquisitiveness, pick up many scraps of useful information; but the powers of reason, of independent thought, of balanced judgment, lie latent in the young child to a very large degree. It is in the vital years from about twelve to sixteen or seventeen that these powers attain working strength, and it may therefore be considered that all which goes before the age of about twelve is merely preparatory, and that the real educational development properly dates from this time.

c. The Transfer to Secondary Schools.—As the artisan classes are taking an increasing share in municipal and national government, the supreme Imperial task of our time is the raising of popular intelligence, and it is as desirable as it will be beneficial to give the artisan as broad an education as is given to those whose privilege it has hitherto mostly been. As yet the greater number of our working-class children must go out at the age of thirteen or fourteen to earn a livelihood, but it is to be hoped that in the very near future a much greater proportion of the children even of poor parents will be able to proceed to a secondary school, especially if they desire and deserve it. So the essential thing at the present moment is to popularise secondary school teaching; to make the lower middle and artisan classes feel that they have as great an interest as anybody in our secondary schools. The narrow ladder must give place to a wide corridor between the primary and the secondary schools.

d. The Present Scholarship System Inadequate and Wrong in Principle.—If this view of the aim of the primary school and of the relationship between the primary and the secondary school be granted, then it follows that our generally existing method of awarding scholarships is wrong in principle as well as inadequate. A local authority offers x scholarships, and primary school teachers far too often look upon the winning of scholarships more as bringing kudos to the school than advantaging the child. They eagerly scan previous years' questions, and do their best to anticipate what questions may next be set; and, on the other hand, the examiner generally tries to set what he thinks the child will not know. Neither is to be blamed. Under present conditions they could hardly do otherwise. The system is at fault. Then the list is announced, and the child with 55·9 per cent. of marks may secure a scholarship, and the next

one with 55·8 per cent. is 'just out of it.' Surely the fact only needs stating to show its absurdity.

The principle, too, is wrong, remembering the new conception of the scope and aim of primary education. Secondary school teachers frequently lament the 'falling-off' of scholarship children, despite the fact that a fair number of such have done well. If there must be a competitive examination, it would be preferable to give the candidates some new work to prepare in the examination room, and judge their capacity and intelligence by their power to get knowledge for themselves, rather than by their power to yield up what has often been so laboriously crammed into their heads.

e. Nomination and Consultation better than Examination.—It would be well if all special preparation could be avoided. It should be possible at the end of the educational year to ask the teachers in primary schools what children desire and deserve to go forward to a secondary school, and, after nomination, the secondary school teacher should meet the candidates face to face; then, by a few skilful questions and by consultation between the primary school and secondary school teachers, a wise selection could be made, a selection based, not upon the throw of a single examination—often too much of a lottery—but upon the child's school record and upon the secondary school teacher's personal opinion of those latent powers which are at this time just beginning to make their presence evident.

f. Desirability of varying Number of Scholarships.—There seems no reason why these scholarships should not vary according to the number of suitable applications. The list of children who may 'desire and deserve' scholarships is not constant, but varies from year to year. There should be no poverty barrier. Maintenance allowances should be awarded where necessary, but no child ought to be transferred to a secondary school unless the parents are prepared to allow attendance for a full four-years' course. For those who cannot do this the tops of the elementary schools should be strengthened in order to give an extended education for a year or two, of a type useful both for a livelihood and for life. That hybrid institution, the so-called higher elementary school, is a needless excrescence.

g. The Future of Bright Children from Poor Homes.—As public money is spent to benefit the State as well as to help on the child, it would appear desirable that much more care should be taken to secure suitable employment for these children at the termination of the secondary school course than is generally taken at present. It seems in one sense a waste of public money to give an efficient higher education to a promising lad, and then find him at fifteen or sixteen years of age starting work as an errand-boy, and even in some cases entering the ranks of unskilled labour. Not but that the errand-boy is all the better citizen for his education; yet it is disheartening to many a bright lad to find the doors bolted against him in the walk of life he would select, because he lacks influence. He should find it possible to serve his town and his country in that station in life for which his capacity and intelligence fit him, remembering Plato's rule, 'that children should be placed not according to their father's conditions, but according to the faculties of their mind.'

h. Correlation of Aim and Co-ordination of Curricula.—It is obvious that the more natural and easy the transition is made from the primary to the secondary school, the less will be the wastage of time and effort in settling down in the new school. To this end there should be periodical conferences on questions of curricula, and, so far as is practicable, a continuity in the scope and aim of the instruction, with the object of rendering easy the passage of intelligent pupils from the primary to the secondary school.

4. *The Scholarship System.* *By* Miss S. Heron.

In this paper the scholarship system was considered from the point of view of the secondary school into which girls are received from the elementary school.

The *age of admission* should be not later than twelve.

The *method of selection* of junior scholars should include nomination by the head teacher of the school from which the girl comes, proving her to be suitable in ability, conduct, health, and home conditions for more advanced work and a wider curriculum. This should be followed by a written examination, held by the staff of the secondary school into which the girl is received, in arithmetic and English, and this paper test must be supplemented by an oral examination as well as by a medical examination of the best candidates.

For intermediate scholars the examination held by the Joint Scholarships Board should be superseded by some recognised examination taken in the ordinary school course, *e.g.*, the Junior Oxford or Cambridge Local.

For senior or leaving scholarships the candidates should have taken some certificate qualifying for admission to a university before leaving the sixth form.

The *monetary value* of junior scholarships should cover school fees, books and stationery, and travelling expenses (if any), with a small margin for incidental outlays. The value of intermediate scholarships should be about half as much again, to provide a maintenance grant and to induce parents to keep a suitable girl at school as long as they can afford it.

The *rejection of the unfit* should be done as early as possible and without hesitation; but, if the method of selection is thorough and careful, not many scholars, once entered, will prove unsuitable. The most usual reason for such unfitness is previous 'cram,' but a wise entrance examination will detect this evil.

Conditions of award.—Scholarships ought not to be confined to pupils from any special class of school, but should be open to all girls, whether previously educated in elementary or private schools or at home. Some should be awarded to girls already in the secondary school who show sufficient merit and whose parents have slender means.

The *duration of tenure* of junior scholarships should depend on periodical reports, but should be generously extended from year to year to satisfactory scholars up to the age of sixteen, *i.e.*, for at least four years.

Intermediate scholarships should be given to a judiciously selected number of junior scholars who have passed a qualifying examination proving them to be able to profit by remaining at school till the age of eighteen. These, again, should be followed up by senior or leaving scholarships for the few who wish to go to the university.

Treatment of scholars.—Scholarship-holders should be welcomed in the secondary school as keeping up a high standard of work and conduct, and helping to break down any tendency to foster class distinctions. Each girl should stand on her own merits, independently of social position or creed. No difference should be made in any way between fee-paying and non-fee-paying pupils, unless it be to bring forward the latter, who by industry or ability have won free places.

5. *The Scholarship System as affecting Preparatory Schools.* *By* G. Gidley Robinson, *M.A.*

Entrance scholarships at the public schools are of great importance to preparatory schools, both from the financial and from the educational point of view.

(i) *Financial.*—Candidates from preparatory schools are by no means necessarily sons of wealthy people. The parents often make self-sacrificing efforts: the schoolmasters do much to help them. For many such boys scholarships are an inestimable boon or even necessary. On the other hand, parents who do not need scholarships are keen to get them; for competition stimulates a boy to do his best, and if successful he makes a good start and is not overlooked in the crowded world of a public school. If elected on the foundation at Eton or Winchester, he has the advantage of living among a picked lot of clever boys. Sometimes scholarships are declined by wealthy people for their sons; but generally they are

regarded as prizes, not as eleemosynary endowments. As a step towards creating a public conscience in the matter, why should not the face-value of scholarships be reduced to, say, the amount of the tuition fee, and only increased on the application of the parent? This would be a matter for private negotiation, and would leave no stigma of poverty on the scholar. The moral effect of such a reform, if required by general statutory enactment, would probably be great.

(ii) *Educational.*—Scholarships are offered by the public schools in order to attract clever boys who will win honours later on at the universities and elsewhere. The system encourages early specialisation, especially in classics. Hence an undue proportion of the time-table in preparatory schools is devoted to Latin and Greek.

Scholarship examinations are at present the only public test of work and teaching in these schools; they set a standard, and so render important service. On the other hand, they dictate the curriculum for all boys, dull as well as clever. The latter can always take care of themselves; but for boys of small linguistic ability, the curriculum is overburdened with languages, and is therefore one-sided and unsatisfactory. It should be framed from the point of view of the boy whose aptitudes have to be discovered, *i.e.*, provide for many-sided interest. This is good policy for the scholar, and essential for the boy of average ability. Ordinary abilities, backed by moral qualities, do some of the world's best work; we cannot therefore afford to neglect them in favour of specially-gifted boys.

The time necessary for a wise readjustment of the curriculum can only be found by postponement of Greek and Latin verse. This might be done without any violent changes of methods and standards. And it is necessary to 'hasten slowly,' for there are rocks ahead in the question of the supply of properly qualified teachers.

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6. *The Scholarship System at Oxford and Cambridge.* *By* H. B. Baker, *M.A., D.Sc., F.R.S.*

The present system of open scholarships at the older universities owes its existence to Richard Jenkyns, Master of Balliol 1819–1854. Until about eighty years ago help was given to students in two ways. There were scholarships, confined to particular schools, districts, or families, and there were servitorships or sizarships, the holders of which did not necessarily possess very high intellectual qualifications, but who were essentially poor men. Jenkyns's system was the offering of scholarships, after a competitive examination, to schoolboys without any reference to the question as to whether the money was or was not needed for their university education. The status of scholars was improved, and they were made to rank in the college immediately after the fellows. In a short time many of the most brilliant boys in public schools were attracted to the universities, and, what was more important, there was an improvement in the work of the schools, which benefited not only the prospective scholars, but also the rank and file of the school. The competition for open scholarships is perhaps keener in our own day than it has ever been, and the success of a school is now gauged, quite wrongly in my opinion, by the number of open scholarships it can claim at the end of the school year.

It has been several times suggested during the last few years that the scholarship system involves a great waste of money, and schemes have been proposed which, while retaining the stimulus of competition, give the money only where it is needed. This seems the only logical position, and were the question as simple as it sounds few would hesitate to adopt one or other of the solutions. The most recent of these proposals is briefly this, that all entrance scholarships should be of the value of 40*l.* a year, and that they should only be increased when the parent could prove that the increase was necessary. On the face of it the proposal seems reasonable, with the one exception that the giving of 40*l.* a year to a scholar who does not need it seems a half-hearted measure.

Exaggerated statements of the waste of money given in scholarships are so

often made that an attempt to arrive at an approximation to the facts should be of interest. The heads of all colleges at Oxford and Cambridge were asked to give an estimate of the proportion of their scholars during the last ten years who could have afforded to reside at the university without the aid of their emoluments. Acknowledgment is gratefully made of the kindness of these gentlemen and of the tutors of colleges in compiling the statistics which it is now possible to bring before the Section. The estimates show that at Cambridge 17 per cent. of scholars could have resided at the university without their scholarships, while at Oxford the proportion is only 6 per cent. But even in many of these few cases it was very largely the opinion of my correspondents that the money given in scholarships was not misused. The head of the college at Oxford which had apparently the largest percentage of wealthy scholars pointed out that they were largely sons of professional men whose incomes are uncertain. In these cases if the father happens to die during his son's university career there is no possibility of the boy's education being completed without external aid. Many have pointed out the difficulty in dealing with the figures supplied by parents with the object of proving poverty. Others consider that if scholarships were made purely eleemosynary the status of scholars would immediately fall, and a condition of things spring up which exists, to their great detriment, in some of the American universities. It must be remembered that the social life of the older universities is one of the most important things to a youth, and anything which would tend to diminish its educational value is much to be deprecated. Considering the disadvantages which the new scheme presents, I would advocate two alternatives. First, let there be a voluntary relinquishment of the emoluments of a scholarship by a wealthy parent, the other privileges of the scholar being retained. It would soon become a point of honour for a wealthy man to refuse to accept money which would be so useful to poor men. Second, let a former scholar who has attained in later life to a position of comparative opulence pay back his scholarships in some way or other for the help of other poor scholars. With regard to the first of these proposals I may point out that it is occasionally carried into effect. At one Oxford college six out of twelve wealthy scholars have during the last ten years refused the emoluments of their scholarships, and isolated instances have occurred at other colleges. With regard to the second proposal, *cum veniret ad pinguiorem fortunam* (when a man has attained to fatter fortune), as the St. Andrews statute has it, he should pay back the money which was the foundation of his fortune. This also is done, and perhaps more often than is known. Occasionally the whole sum is paid back to a college, but more frequently the former scholar, out of the not very fat fortune of a schoolmaster or college tutor, pays the sum back in helping poor scholars at the university.

Either of these systems of relieving college funds would, if backed by the force of public opinion, relieve an amount of hardship and poverty which is scarcely realised by any who have not been either poor scholars themselves or been brought into intimate contact with them. The cost of living varies very greatly at different colleges. It is possible to live with economy at many colleges on 120*l.* a year. Two of my own pupils at Christ Church have managed with self-denial to limit their expenses to 110*l.* a year. Since an open scholarship is 80*l.* a year, and school-leaving exhibitions may give a man another 20*l.* a year, it is not difficult to see that the very poor man has still need of assistance. Most colleges have an exhibition fund from which grants are privately made to the poorest students, and anyone who is willing to pay back his scholarship by the help of which, it may be, he has attained a good position, could hardly do better than contribute the money to such a fund.

7. *The Scholarship System at a Residential University.* *By* Professor H. A. Miers, *M.A., D.Sc. F.R.S.*

At a residential university like Oxford two main objects are to be secured by the scholarship system: (1) the opportunity for poor lads of marked ability to get

admission to the university; (2) the encouragement of an intellectual class of student and the maintenance of a body of scholars who can live together to their mutual benefit. To these may be added (3) means of endowing industrious lads who are unable to win the greater scholarship prizes in open competition, but require endowment if they are to live at an expensive university, and (4) the encouragement of special studies by special scholarships.

With regard to (1) there is very little now to prevent any lad of really marked ability from winning his way to the university by means of scholarships, however humble his origin. So far the present system is a success. But it is also quite certain that, at Oxford, scholarship money is spent on many young men who could afford to do without it, although the estimates of how many vary greatly. With regard to (2), it is most important that boys of ability should come together and form an intellectual class in the university, and that every college should have a considerable number of them, but that is no reason why they should all receive a uniform endowment of about 80*l.* a year. It has been suggested that all scholarships should be of a nominal value, say, of 40*l.* a year, and should only be supplemented by an additional endowment raising them to 80*l.* or more for those to whom it is really necessary. This would liberate funds which would render it possible to bring to the university, and to maintain there, many of a highly deserving class, mentioned above under (2), namely, the industrious boys who are not quite up to the open scholarship standard, but who have everything to gain from a university career, and are a great strength to the university and the colleges. Call them exhibitioners or what you will, the point is that they should not be elected merely on open competition, but to some extent on personal recommendation.

The present scramble for scholars not only between the two older universities, but also between the various colleges at each, leads to no useful result. It sometimes ends in very indifferent competitors being left for those colleges which come late. Add to this the worry and inconvenience caused by sending boys up from school for several successive competitions, and it is clear that there is room for more combination and organisation on the part of the colleges. The group system, by which several colleges combine and hold the examinations together, is a great improvement on the old independent system, and has been more developed at Cambridge than at Oxford. A college objection to large groups is that, owing to the number of candidates, there is no opportunity for the examiners to become personally acquainted with them; but if the examination were held only twice a year it might be made more prolonged and more thorough than it is now, and give ample opportunity for the examiners to study their candidates on behalf of their respective colleges. From a large group system it is only one step to a still larger combination by which scholarship examinations would be really conducted by the university, say, twice a year, and the scholars drafted into the various colleges. This would of course leave each college free to reject an offered scholar, and would not preclude the possibility of a certain number of college scholarships in addition to those administered by the university. The endowments mentioned above for boys below the highest scholarship standard might well be exhibitions administered by the colleges themselves. That such an arrangement is not impracticable is shown by the working of the Rhodes scholarships.

One of the great grievances at the present time concerning the scholarship system is the fact that the examinations are constantly becoming harder and are tending more and more to enforce specialisation at schools. Anything which will prevent this would be a gain, and it would be far easier for the university as a whole to keep the standard uniform and general than for the individual colleges which are in competition with each other. It is as easy to select scholarship boys of real promise from a crowd of competitors by means of a fairly simple and wide examination as by the more special and advanced examination which now prevails, and there is perhaps no reason why the same papers, including classics, mathematics, science, English, and modern languages, should not be set to all competitors alike, though it might be necessary to preserve a distinction between

scholarship examinations for modern side boys and those on the classical side. But such things as examinations in classics or mathematics, or history, or science alone ought to be unnecessary; so long as they exist there is little reason why scholarships should not be given also for geography, or divinity, or modern languages and each of the other subjects which form part of the ordinary school curriculum.

But if scholarships in special subjects should be discouraged for schoolboys, they should be encouraged for another class who are at present almost entirely overlooked by our university system—namely, the class of advanced students. A few of them from favoured countries are now provided for by the Rhodes scholarships at Oxford, but it is remarkable that while we are establishing all sorts of advanced courses, diplomas, and research degrees, we have established no scholarships to enable the poorer student to enter upon these courses.

A kindred need, which is also very often overlooked, is that for some provision whereby a scholarship may be prolonged for post-graduate study. Nothing is more valuable, both for a university and for its better students, than the maintenance of a considerable body of young men employed in research or teaching work, or in advanced study, under the direction of the university teachers.

Too many men drift away into professions or occupations for which they are not best fitted merely because they cannot afford to stay on at the university at the exact time when a year or two of advanced work would supply just the intellectual stimulus that they require, and would enable those who possess some originality to show their capabilities.

Another matter of supreme importance is the influence of the scholarship system upon school teaching. The present harmful overtraining of certain boys in special directions, and the consequent neglect of others, can only be prevented by examining on the normal curriculum and by refusing to allow the examinations to increase in difficulty as they do now; in other words to ensure that the scholarship examinations shall set the normal standard of curriculum for the abler boys at schools, and not a standard which is only attainable by a few highly trained boys of quite special ability, just as the ordinary entrance examinations to the universities, if they are to he maintained, should set the normal standard of curriculum for the ordinary boys.

Considering the enormous expenditure of time and money throughout the country upon examinations, it might be profitable to consider how far the present examination system, with its feverish writing against time, might be partly replaced by the more rapid, more economical, and more personal *viva voce* examination.

At present many a teacher lives almost as much by examination work as by remuneration for legitimate teaching work; if some of the money now spent upon the payment of examiners were saved for the better payment of the teacher very considerable advantages would be gained. This is, however, a matter that concerns examinations in general rather than scholarships in particular.

To conclude: the suggestions made amount to this, that school scholarships should be by examination of a less special character, should be in general of less value, and should be administered by the university; that exhibitions given otherwise than by examination should be administered by the colleges; that a certain number of scholarships should be awarded for advanced or post-graduate work; and that there should be more provision for prolonging ordinary scholarships for these purposes.

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8. *The Scholarship System.* *By* Rev. A. A. David, *M.A.*

The scholarship system is at present based on two general principles. The first and original principle is the assistance of those who can prove their fitness for higher education, but without monetary aid would be unable to avail themselves of it. It is somewhat remarkable that in a country not specially inclined to respect intellectual distinction as such, the position of the 'poor scholar' has developed into one of honour. This leads to the second principle, which is the

recognition of superior ability and attainment by means of a special status, carrying with it a fixed emolument.

The difficulty of the existing situation is largely caused by the fact that these two principles are in confusion. Open competition has naturally resulted in the bestowal of emoluments on candidates who distinguish themselves in the examination, but may or may not be deserving of financial assistance.

In devising a solution of this difficulty two things must be borne in mind. Firstly, it is most important that students needing such assistance should not be separated from those who deem the distinction worth winning for its own sake, but cannot, except in a very few cases, bring themselves to refuse the emoluments. Secondly, it is important that the distinction should not be entirely dissociated from the money grant which seals its value.

A possible reform would be to reduce the money value of all scholarships to something quite nominal, but sufficient to serve as a symbol of the intellectual distinction.

The remainder of scholarship revenue might then be converted into augmentation funds from which grants would be made privately in full proportion to need. Experience already gained in administering small funds both at school and university shows that such an augmentation of nominal scholarships, though involving delicate investigations and sometimes difficult decisions, would not be impracticable even on a very large scale.

MONDAY, AUGUST 5.

The following Report and Papers were read:—

1. *Report on the Curricula of Secondary Schools.*—See Reports, p. 422.

2. *Education and Evolution. By* Rev. A. E. Crawley, *M.A.*

Though the literature of education during the last fifty years has been voluminous, the problems of education have never been examined on a sufficiently large induction of facts, and the biological and evolutionary point of view has been entirely ignored.

The principles which underlie the education of to-day are entirely unsatisfactory: they are fortuitous, traditional, or opportunist. (1) The curriculum is overcrowded with subjects; many of these are not educational, in the proper sense, for real life; (2) the results are *nil*; vulgarity, squalor, obscenity, hooliganism, seem to increase with the education of the lower orders, while general capacity and power of thought have not increased.

Individuality is actually destroyed. From a study of the subject in its anthropological and psychological aspects, and from a long practical experience of teaching, it would appear that—

1. The education of a savage child is at once practical and liberal, and offers valuable lessons for our purpose.
2. Education should make, not good workmen, clerks, or citizens, but men.
3. The biological significance of childhood is all-important; the child represents the future of the race in two senses of the phrase. The superficial and immediate meaning is obvious, but the other and deeper meaning, which is not generally understood, is that in terms of evolution the child is higher in the scale of development than the adult, just as the infant ape is much nearer to man than the adult ape.
4. The importance of physical culture and athletics is not sufficiently understood. The neuro-muscular system is at present either not exercised, or exercised improperly, or overworked.

5. We ignore the delicacy of children's nerves. Especially fatal is the fallacy of brain-exercise: the brain is not a muscle; to venture on a paradox, there should be no work at all in schools. Mental fatigue is daily forced upon children to their incalculable injury.

6. Subjects of curriculum. Two prime needs are: (1) The encouragement of the imagination, which in childhood is actually at its best. (2) The exclusion of useless subjects.

Useless subjects will not pass the following tests: (*a*) A child must learn the world of Nature, and later of men, as we now know it. This means Nature-study and science generally. It must learn the various aspects in which a thing is knowable—surface, area, form, numerical values. Only so much mathematics is necessary as is required to work with science and mechanics. (*b*) It must know itself. (*c*) It must learn to express its knowledge and co-ordinate it.

History in the ordinary sense is useless, but biological and evolutionary history is essential.

No languages other than the vernacular are to be learned. The old plea of 'culture' involves many fallacies. Culture comes from luxury and refinement of surroundings: it cannot be taught, and its only importance is in the æsthetic side of life.

As to the plea of 'formation of character,' there are many fallacies enshrined in this and in the ordinary conception of duty.

Ideal teaching should be the answering of children's questions in terms of the knowledge already acquired by themselves.

3. *The Secondary School Curriculum in France, with particular reference to Instruction in Modern Languages. By* Professor Léon Morel.

Since 1902 a complete reorganisation of the whole course of studies has been imposed upon all State schools. After a first stage of primary or elementary teaching which applies to boys from a very early age, and already comprehends a teaching of one foreign language, secondary teaching proper begins with the sixth form (boys of ten on an average). The whole course, then extending over seven years, is divided into two cycles—one of four years (sixth, fifth, fourth, and third forms), the other of three years (second and first forms), philosophy or mathematics. The first cycle comprises two sections throughout the four years. In one of them (Section B) no Latin is taught; in the other Latin is taught from the sixth form; Greek is optional from the fourth form. In all classes of both sections living foreign languages are allotted as many as five hours a week.

In the second cycle four sections are established in the second and first forms. One, Section A, is characterised by the teaching of Latin and Greek; Section B by that of Latin and foreign languages; Section C by that of Latin and sciences; Section D by that of sciences and foreign languages. The last is the normal course followed by the boys who, in the first cycle, have learnt no Latin. But Section D is equally accessible to boys who, having belonged in the first cycle to Section A, choose to abandon the study of Latin. In all four sections living foreign languages are taught. They receive two hours a week in Sections A and C, seven hours in Sections B and D. Of those seven hours, three are allotted to the language learnt by each boy previous to his entering the second form, and four to the study of a second foreign language. At the end of the first class boys undergo the examination for the first half of a bachelor's degree, different tests sanctioning their various programmes of study.

Boys who have passed successfully that first B.A. examination enter either the class of philosophy or that of mathematics, both comprehending a further study of living languages, to the rate of two hours for some and of three for such as wish to go on with the study of two languages.

It will be seen from this brief summary of the system that a strenuous effort is being made (1) at securing a varied and supple curriculum which may ensure both

practical usefulness and disinterested culture, and (2) at giving to foreign languages, either entirely or partly, the share in the formation of young minds which was previously considered as a privilege of ancient languages.

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4. *Conditions of Science Work in Secondary Schools.* *By* R. E. Thwaites, *M.A.*

In a paper on the 'Internal Economy of School Science,' read before the Public School Science Masters' Association in January 1907, figures were presented relating to conditions of science work in thirty-six public schools. More recently similar data have been obtained from about the same number of secondary schools, working in conformity with Board of Education regulations.

In both cases information was asked for on the following points: Number of boys taking science in (1) general course, (2) special course; average number in class; number of hours per week for (1) general course, (2) special course; number of science masters; number of laboratory assistants; approximate annual expenditure for science; and answers to the following questions: Do you consider your present arrangements to be adequate in respect of—(1) laboratory accommodation, (2) laboratory equipment, (3) staff, (4) laboratory assistants?

The average results may here be given:—

Public Schools.—In twenty-nine schools 60 per cent. of the boys take science: in twenty-three of these the average percentage of boys in the general course is ninety-five, the remainder being specialists. The number in class for twenty-seven schools is 21·5 in the general and fourteen in the special course. The time for the general course is four hours a week, usually divided between chemistry and physics, and for the special course twelve hours. In eighteen schools the annual expenditure per boy was about 1*l.* Chemistry costs more than physics for maintenance. In twenty-three schools there is a science master for every seventy-six boys and a laboratory assistant to every 147 boys. Sixty-five per cent. of the correspondents were satisfied with their laboratory accommodation, 71 per cent. with equipment, 77 per cent. with the number of the staff, and only 58 per cent. with laboratory assistants.

Secondary Day Schools.—All boys above twelve years of age take science. The percentage of boys in the general course, lasting four years, is 94, in the special course 6. The average number in class in the general course is 22·6, in special course 8 or 9. The number of hours for science in general course is rather over four a week, and in special course from eight to fifteen. The work is usually divided between chemistry and physics; very little biology is taught. The annual expenditure per boy for apparatus and chemicals is 8*s.* 6*d.*, or 2*s.* for one hour of science a week. The average number of boy-hours a week for one science master is about 310. There is one laboratory assistant to 218 boys. Ninety per cent. of the correspondents are satisfied with their staff, 77 per cent. with laboratory accommodation, 80 per cent. with laboratory equipment, and 50 per cent. with laboratory assistants.

It will be seen that the ratio of specialists to boys in a general course is roughly the same in the two classes of schools. In the matter of expenditure the day schools are markedly inferior to public schools. In both there are too few laboratory assistants. The consequences of this misguided economy are that the time of the science master is wasted in drudgery which could be performed less expensively by an assistant, and opportunity for preparation of experiments is lacking.

In answer to the question, 'What do you consider to be the maximum size of a laboratory division for successful work?' the average reply from thirty schools was: Twenty boys in the lower classes, twelve in the higher. It need not be said that these figures still represent only a pious aspiration in many cases.

Another question addressed to the same schools related to the advisability of teaching experimental mechanics as part of the science course. The answers

showed a strong feeling of the value, and even necessity, of such a course as a preliminary to all advanced work in physics.

It is hoped that this report, fragmentary as it is, may be of some use to educationists and those interested in the supply of secondary education, as indicating the present conditions under which science work is prosecuted in public schools and the better class of secondary day schools.

Joint Discussion with Sections D and K on the Teaching of Biology in Schools.—See p. 547.

TUESDAY, AUGUST 6.

The following Papers were read:—

1. *The Need of a Scientific Basis to Girls' Education from a Domestic Point of View.* *By* Professor H. E. Armstrong, *Ph.D., LL.D., F.R.S.*

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2. *The Teaching and the Teacher in Evening Technical Schools.* *By* J. H. Hawthorn, *M.A.*

In considering curricula, too little account is often taken of the question 'What is the type of student attending Evening Technical Schools?' The type of student is even now rapidly changing. Ten years ago our schools were largely occupied in catering for an army of adult workmen whose previous education, scanty as it was, had been long forgotten. Looking back over these years, a progressive lowering of the average age of the students is observed. In the case of the adult student all we could hope was to give him some scraps of knowledge which he could at once fit into his trade requirement.

To-day a much larger view of the functions of a Technical School may be taken, and the fact may be emphasised that the beginning of things scientific is undoubtedly Pure Science. There has been so great a demand for Applied Science of late years that a murmur of dissent may be expected when a recognition of this principle is asked for, but we may fairly ask the question whether we are not overdoing the so-called application of science.

What students do we find come out best in our evening classes? Undoubtedly those whose previous work has been in pure science. We may teach chemistry of the boot trade, or even chemistry for the engineering trade, but a course of chemistry as chemistry will lay a much better foundation for the later application of it than to begin at once dovetailing chemistry to leather or steel. This attitude may be criticised by pointing out that much of the *application* of science (so called) has been rendered necessary by the fact that we must *attract* the evening student, and that we have no compulsory evening school attendance scheme. Experience shows, however, that evening students worth keeping and worth teaching are generally ready to be advised as to what course to take and how to take it. Seekers after Applied Science are mainly hunters of wrinkles and tips which may be useful in the factory and can be obtained with a minimum of mental effort.

Nevertheless, a technical school ought certainly to provide 'Applied Science' as its chief educational item, but it ought to be divided into two departments: The higher should be the applied science department, and this should be the *trade department* also. Leading up to this should be the pure science side, as preparatory to it. No student ought to be allowed to take a trade class (as trade classes are known in Leicester) unless he has laid a foundation of pure science in the preparatory department.

What of the plumber, the shoe-hand, the bricklayer, and the carpenter? Will he devote winter after winter to a painful struggle with geometry, physics,

mathematics, &c., while he desires a knowledge of struts, bonds, beams, lasts, pipes, and all the other trade paraphernalia? It must be admitted that we cannot expect this of him if he comes to the Evening School with ten years' shop experience and ten years' blank after his schooldays. There are nevertheless a few, even of this type, who come at the age of twenty-five entirely ignorant, but with an appetite for knowledge sharpened by a rude awakening to their incompetency. These of course do well, but the great majority of older students barely attain mediocrity. The adult student in evening technical schools is gradually disappearing, and though his elimination is slow, yet we shall best study the interests of our pupils if we take special care of our younger members, and whether they get their preliminary training in science in the school itself or in some preparatory school, one condition of admission to any trade class ought to be the possession of at least a modicum of pure science.

The question of the best type of man to teach in evening technical classes is a very difficult one, but we are helped to a solution if clear ideas are held about the curriculum. If we assume the existence of the preliminary course of pure science, &c., the choice of a teacher for this will not be a source of much anxiety. When we come to trade subjects we are on very debatable ground. The usual evening teacher works all day in the factory, and comes one or two evenings to take charge of a trade class in the technical school. While appreciating the splendid work that has been done by these men, it cannot be an ideal system which only brings a teacher into contact with his teaching when his mind and body are carrying the burden of a hard day's work in the factory or workshop. The chief fault of the system, however, is that the teacher has no opportunity of correlating his work with that of other teachers, and he and his class become an isolated community. The average teacher of this type is, as a rule, lacking in general scientific training, and usually his knowledge of trade methods and processes is in inverse ratio to his knowledge of scientific matters. He has never been taught to teach, and frequently has the haziest notions as to the capacity of his students. In fact, the 'odd evening' artizan teacher is not a satisfactory solution of the difficulty.

The alternative is, of course, to employ the science teacher who has probably spent the day in another school. In this case we get rid of one difficulty, but meet another perhaps more serious. The teaching of trade subjects requires trade knowledge, and there are hundreds of records of classes wrecked for lack of this vital necessity in the teaching. Experience shows that the best results are obtained by a blending of these two methods. A science teacher with a competent artizan demonstrator will ensure both the correct development of the subject taught and the welding of the scientific principles with the workshop application of them.

Of course, where day classes are held, and it is possible to employ teachers for full time, the difficulty largely cures itself, but the question of 'Up-to-date-ness' needs very careful watching. A man who occupies his whole time in the teaching of the principles of any trade must, by his separation from workshop conditions and developments, inevitably become out of date and behind the times; and it is here that the good will of local manufacturers can be utilised to great advantage. When the teacher is known to, appreciated by, and keeps in touch with local factory owners, and is encouraged to visit factories and manufacturing works, he keeps abreast of the trade in its growth, and best satisfies the demand in our schools for that desideratum, a technical teacher.

In working the scheme consisting of a trade teacher *plus* a science teacher, the position of the two men in relation to the class must be decided, partly by the qualifications of the men themselves and partly by the administrative possibilities. In the Leicester Municipal Technical School a plan is adopted which has worked so far with excellent results. One member of the staff devotes his time to what may be termed technological science. He works in close conjunction with the several trade teachers. With slight modifications to suit the different trades, the same course of introductory science is suitable for many classes, and the detachment of such a teacher for this purpose enables him at the same time to study the trade questions to an extent sufficient for him to bring his teaching more or less

closely into line with the requirements of the trade teacher. No doubt in most schools one such man, with his energies devoted altogether in the direction indicated, would find his time fully and profitably occupied, and have on the trade teaching a beneficial effect where such influence is most wanted.

3. *Problems of Trade Education considered in relation to our School System.* *By* C. T. Millis, *M.I.Mech.E.*

The object of this paper is to point out the several problems connected with the continuance of education beyond the elementary school stage in the direction of technical or trade education, and to make suggestions that may be useful in deciding whether the higher elementary school or some other type of school is the best suited for the purpose. There is a general consensus of opinion that some reforms are needed in our elementary school education to make it an effective preparation for the battle of life, especially for those children who will take up industrial work. The time is ripe for the discussion of the question, seeing that there is an increasing number of persons who feel that elementary education has hitherto given too much attention to the requirements of those going into clerical occupations and practically none to those of the children going into trades. The education has been too bookish, has tended to increase the taste for mere clerical work, and has not impressed children with ideas of the dignity of labour. The bright children wishing to enter the office or the Civil Service, or to become teachers, have had opportunities of entering secondary schools by means of scholarships, whilst, broadly speaking, there have been no schools of a practical character for children to enter who are going into trade, or scholarships provided which would assist them.

There is a great tendency to regard the effort to make good workmen as utilitarian and to a certain extent as derogatory compared with the humane side of education, though this side is often quite as utilitarian, in that it is given as a means of piling up marks and securing coveted positions in the professional world. The humane and utilitarian subjects of education are not mutually exclusive; each has power to make noble characters with high ideals for work, and education has no other object. The inference which seems to lie at the root of popular notions of culture, that the more useful a subject is the less is its culture value, is wrong.

New conditions in our industrial system, owing to the introduction of machinery and subdivision of labour, combined with decline in apprenticeship, make it necessary to provide a broad basal training in our educational system for those who are to become skilled workmen, which will discourage young workmen from being content with a knowledge of one or at the most two branches of whatever trade it may be, and will render them more efficient all-round men, able to cope with the ever-varying conditions of manufacturing industries. The absence of such knowledge tends to increase the number of unemployed. The importance of the subject is recognised by the formation of Apprenticeship Committees, Reports of Education Committees, Mr. Edric Bayley's pamphlet on 'Industrial Training in Elementary Schools,' and Circular 604 issued by the Board of Education. All these, as well as the establishment of several types of trade and technical schools, notably in London, are evidences of a feeling of unrest.

The types of schools may be considered under three heads:—(*a*) Trade schools for girls; (*b*) technical (specialised) trade schools for boys for particular trades; and (*c*) technical or preparatory trade schools.

Schools of Type (*a*).—Highly specialised training schools for girls, between fourteen and sixteen years of age, in needlework trades, as dressmaking, ladies' tailoring, waistcoat-making, upholstery, &c., modelled on Parisian schools. These take the place of apprenticeship up to the 'improver' or assistant stage, but would be more valuable if preliminary training were possible for one year between elementary and trade schools.

Schools of Type (*b*).—For boys, between fourteen and sixteen years of age

hoping to become foremen and managers, chiefly from higher elementary and secondary schools. Engineering and bakery trades chiefly dealt with. These only provide for the few bright boys and only touch the fringe of the question.

Schools of Type (*c*).—For boys who will enter trades at between fifteen and sixteen years of age, suitable for the mass, and providing preparatory trade training; specialisation deferred to the last year. Such schools are safest under modern conditions in that too early specialisation and late age of entering trades are avoided. No special ability is required. Fundamental principles relating to handicraft are taught; no attempt is made to replace workshop experience, but merely to shorten period of learning a trade. Practical mathematics, science, drawing, and workshop practice in relation to various groups of trades are taught. The opinion of manufacturers is in favour of better trained workers, of whom they say there is a scarcity.

The State and educational authorities for many years have failed to grapple boldly with the question of providing better opportunities for the training of the industrial workers. There has been an indecision of policy; first we had a few day classes in the same subjects and under the same syllabuses as those suitable for evening classes in science and art; next the organised science schools under similar conditions, which were really not organised schools; these were improved, and we had what became known as Division 'A' type of schools, which were afterwards transferred from the management of South Kensington to Whitehall on the reorganisation of the Education Department to a Board of Education. The Division 'A' type of schools was squeezed out of existence by the Regulations for Secondary Schools, and clause 42 of the Regulations for Evening Schools was introduced as a means of dealing with schools of types other than secondary. Lastly, we had the Higher Elementary School Minute, and by a process of evolution we are coming to the trade schools of various types.

The several types of trade schools are better suited to the needs of the times and are more needed than higher elementary schools. These trade schools, in close connection with or in technical institutes, and working under clause 42 of the South Kensington branch of the Board of Education, will be a greater success than any schools under the regulations of the Whitehall branch—that is, they should be administered under codes drawn up by those who are intimately in touch with development in technical work.

To get the full value out of such trade schools there must be reform in our scholarships system and in our elementary schools. The reforms most needed in our elementary schools are smaller classes, a simplified curriculum, fewer special subjects, more correlation, and improvements in the teaching of arithmetic, which must be taught in connection with geometry from an early age and be combined with manual work. Manual work must form a real part of the school work and not be looked upon as a special subject.

Close co-ordination is needed between the work of the elementary school and that of the trade school, so that children will enter them better prepared between thirteen and fourteen years of age, and one year's work of the trade school course will be saved.

The important general principles to be considered in the establishment and management of trade schools are:—

(*a*) Plan the school course to permit boys to enter any given trade at the right age.

(*b*) Co-ordinate the work at the beginning with that of the elementary school if possible, and *vice versâ*.

(*c*) Co-ordinate the last year's work with the system of apprenticeship followed in the trade to avoid waste of time.

(*d*) Watch the labour market in order to guard against mistaken specialisation.

(*e*) Secure the right kind of teacher.

Properly managed by co-operation of parents, teachers, employers, and trade-union leaders, there will be no opposition. An adequate supply of well-trained teachers in touch with the requirements of trade is necessary to teach the science

subjects cognate to various trades, and for the special trades subjects the teacher must be a person who has had actual trade experience of workshop and factory conditions.

4. *Day Trade Schools for Girls.* *By* Mrs. J. RAMSAY MACDONALD.

The experiment of day trade schools for girls is still in its infancy in this country, but the promising infant has a great future before it. The standard of wages and conditions of work of women in industry is even lower than that of men. This is due to the fact of woman's double work—wage-earning in factory or workshop and the responsibilities of home. The former is apt to be looked on as temporary and comparatively unimportant, whereas men look upon their trade as their life work. This tendency is disastrous to the four million women wage-earners of the country.

To raise the conditions the training for industry must be taken more seriously. At present there are few opportunities for such training. Evening classes are comparatively valueless after girls have worked at trade all day. The Women's Industrial Council has pressed upon the London County Council the need for day trade schools for girls. In October 1904 the London County Council started the first of these—that for waistcoat-making—at the Borough Polytechnic. Now there are, in addition, schools for dressmaking and upholstery at this polytechnic. Also there are classes for ready-made clothing and upholstery at Shoreditch Technical Institute; for dressmaking at Paddington and Woolwich; and for dressmaking, corset-making, and ladies' tailoring at Morley College—to be moved in the autumn to special premises in Westminster, where classes for laundry work are also planned. The broad lines of instruction are the same in each.

Altogether 280 girls are now receiving instruction, and this number will be increased in the autumn. The pupils attend after leaving elementary schools, most of them having scholarships with maintenance grants, and the course is about two years in length; six half-days a week are devoted to trade teaching; four half-days to general instruction, including art work, bookkeeping, writing of business letters, and so forth, in close connection with the trade work. The trade teachers are in each case women who have come straight from good positions in the workroom, and are closely in touch with trade methods. Each class also has an advisory committee of trade experts, employers, foremen, and others, who visit regularly and give most helpful criticisms and suggestions important to gain the confidence of the trade. Mrs. Oakeshott, the L.C.C. organiser, gains knowledge of conditions in workshops and factories, and helps schools to keep up to date.

The girls begin with easy exercises, and soon proceed to more and more varied and elaborate work, instead of beginning, as in the workroom, with running errands and being kept at drudgery tasks to suit the convenience of older workers. The fundamental difference is that in the school the pupils' development is the first consideration; in the workroom, the customers' convenience. The youngest or slowest pupil has the special attention of the trade teacher and the expert advisers, and the use of good materials to practise on, even at the risk of spoiling them. They are also taken to see the best shops, museums of art work, and so on. Another especial advantage is that the hours are short, and the pupils do not get the backache, anæmia, and general weariness which fall to the lot of the girl of fourteen who goes straight from school to work ten and a half hours, or even more, daily in the season.

It is remarkable to see how the girls respond to this teaching. Girls of thirteen and fourteen manipulate blouses and evening dresses in best West-end style; make waistcoats which evoke the enthusiasm of their teacher, who herself 'sees something fresh to admire in her trade every day'; and at their art lessons design ornamentations and traceries for embroidery which are tasteful and graceful. The girls are at first made to do the work thoroughly and

carefully, without being hurried; but during the second year they are gradually speeded up and made to work to time. We have not yet much knowledge of what the girls can do when they go out into the trade, but so far as we have any, amongst the Borough scholars, it is encouraging.

It is hoped that the girls now being trained will be equipped by their thorough grounding and insight into all branches of the trade and their higher level of general knowledge and intelligence to rise to the best positions in the trade. If the numbers are increased and the operations widened, the level of the average worker will be raised and every girl will be given a chance of being a good all-round hand, taking pride and pleasure in her work; whilst the union in the school of the art and science teaching with the practical details of industry foreshadows a gradual revolution in our trade methods which will raise our industries to a perfection hitherto only pictured by dreamers and idealists.

5. *Technical Training of the Rank and File.* *By* J. G. Legge, *M.A.*

The public is more alive to-day than ever it was to the necessity of technical training, but the avowed end is often merely the training of captains of industry, to the neglect of the rank and file. The need of capable and resourceful workmen is quite as great as that of experienced foremen and scientifically trained managers or directors. Moreover, the workman should be furnished with such an equipment in boyhood as will enable him by steadiness and by study in youth and early manhood to rise through the ranks of foremen to that of manager or director.

But the public is still perplexed to some extent by a confusion in educational ideals. This confusion may be traced all through the history of the theory and practice of education, and is due to the continual conflict between the intellectual and the practical ideals of education. One party has always laid stress on giving all children what is called a liberal education, interpreting this as an education which is largely literary and linguistic, and if it has any direct bearing on the future occupation of a child points to a professional or commercial career, not that of any horny-handed son of toil or mechanic. The other party has considered the main business of education to be the training of a child to follow the line of life circumstances are likely to necessitate, and mistrusts the introduction into school of subjects which might tend to give the child a distaste or to unfit it for such employment as is likely to fall to its lot. The real problem in education is now, as always, how to effect a compromse between the two ideals. To make the ladder of education a real one, one must see that the bottom rungs are there, so that the child, from the very depths, can step on to it without having to be hoisted. The circumstances of many children demand that their manual activity shall be just as carefully cultivated from early years as their intellectual faculties; hence the need for dovetailing into each other the industrial and the literary or intellectual elements of their training. Consideration ought to be given to the bearing on this point of the change in the relation of the home both to school and to work brought about by the industrial development of the last century.

Evidence of the value of industrial training is afforded by a study of the movement in schools under the control of the Admiralty, the War Office, the Home Office, the Local Government Board, and various voluntary associations for the care of orphans and the like. It is clear that what is known as hand and eye training, and weekly lessons making up a course of manual instruction or handicraft, are inadequate. The main ideas underlying all satisfactory schemes of industrial training are the following, every one of which requires full attention:—

The acquisition of the workman's touch.
The art of handling every tool of a trade to the best advantage.
The full understanding of the materials one has to work upon.
The capacity to plan out as well as to execute a piece of work.

It should not be difficult to devise a curriculum for elementary schools alternative to the literary and commercial curriculum generally pursued. The first step toward this curriculum would be to divide a school day clearly into two sessions, the morning session being devoted mainly to the literary and intellectual side, covering such subjects as English, arithmetic, writing, geography, history, and the laws of health, and the afternoon session to what may be called the practical and recreative and constructive elements—drawing, singing, physical training, manual work of the most varied kind—affording full scope for originality both in teacher and child, and housewifery for girls. It should be clearly understood that there is to be correlation between such subjects as arithmetic taken in the morning and such manual work, whether by boys or by girls, as is taken in the afternoon, and similarly between any instruction in elementary science and the manual occupations taken. Demands for such a curriculum were recently put forward by the Physicial Deterioration Committee in its report; by Prof. Sadler in his Presidential Address to the Educational Science Section at the meeting of the British Association in 1906; and by the president of the National Union of Teachers at the annual conference in 1907.

Incidentally the advantage of such a curriculum will lie in the improvement of the conditions of the classes of the population most exposed to physical deterioration, and in helping to counteract some of the deadening influences too often involved in the conditions of modern industry. For the principle at the root of such a curriculum high authority can be quoted. There are physiologists of eminence who are ready to support Mr. C. G. Leland's contention that 'from seven to fourteen years of age a certain suppleness or knack or dexterous familiarity with the pencil or any implement may be acquired that diminishes with succeeding years'; and the following maxim from Goethe is worth pondering: 'In all things to serve from the lowest station upwards is necessary; to restrict yourself to a trade is best. For the narrow mind, whatever he attempts is still a trade; for the higher, an art; and the highest in doing one thing does all, or, to speak less paradoxically, in the one thing which he does rightly he sees the likeness of all that is done rightly.'

EVENING DISCOURSES.

FRIDAY, AUGUST 2.

The Arc and the Spark in Radio-Telegraphy.
By W. Duddell, *F.R.S.*

The discovery by Heinrich Hertz between 1887 and 1889 of experimental means for the production of electric waves and Branley's discovery that the conductivity of metallic particles is affected by electric waves form the foundation on which, in 1896, Signor Marconi built up his system of wireless telegraphy.

Many of the early investigators certainly had glimpses of a future system of being able to transmit messages without connecting wires, for as early as 1892 Sir William Crookes predicted in the 'Fortnightly Review' the possibility of telegraphy without wires, posts, cables, or any of our costly appliances, and said, granting a few reasonable postulates, the whole thing comes well within the realms of possible fulfilment.

Two years later Sir Oliver Lodge gave his memorable lecture on the work of Hertz, and carried the matter a step nearer the practical stage.

There will not be time to dwell to-night on the early history of the art and its development. It will be necessary, however, to explain some of the fundamental properties of signalling by means of Hertzian waves in order to be able to bring out clearly the relative advantages and disadvantages of the two rival methods now in practical use for producing Hertzian waves for wireless telegraphy.

The fundamental part of the transmitting apparatus may be said to consist of a long conductor, generally placed vertically, in which an alternating or oscillating current is set up by some suitable means. Such a conductor radiates energy in the form of Hertzian waves at right angles to itself into space, in very much the same way that an ordinary candle sends out light in all directions. This radiation, though it is strictly in the nature of light, is invisible to our eyes, as the frequency is too low.

If we set up any other conductor approximately parallel to the first, there will be produced in this second conductor alternating or oscillating currents having the same frequency as those in the first conductor, and which can be detected by suitable instruments.

The simplest, and one of the earliest methods for producing Hertzian waves for use in wireless telegraphy consisted in charging up by means of an induction coil a vertical insulated conductor, which was allowed to discharge itself to earth by means of a spark taking place between its lower end and another conductor which was connected to earth. To detect the Hertzian waves, Marconi employed an improved form of the Branley filings tubes, which is known as the 'coherer.'

In order to transmit messages the radiation is started and stopped so as to form short and long signals, or dots and dashes of the Morse code, out of which the whole alphabet is built up in the well-known way.

As I have already stated, the radiation takes place round the vertical conductor approximately equally in all directions. Suppose that I set up my transmitting apparatus here in Leicester, a receiving station set up either in Nottingham, Derby, Rugby, or Peterborough would be able to receive the message equally well. Should I wish to send a message from here to Nottingham at the same

time that Derby wishes to speak to Rugby, then the receiving station at Nottingham would receive both the message from Leicester which it should receive and the message from Derby which it was not required to receive.

To get over this difficulty, known as 'interference,' a large number of devices have been patented. The most successful in practice is syntony, or tuning: in this method each station has allotted to it one definite frequency or tune, and the apparatus is so arranged at each station that it will only be affected by messages which are radiated by other stations on its own frequency or tune, and not by any other radiations. To take a musical analogy, supposing I had somebody who was either deaf to all notes of the piano except, say, the middle 'C,' or had such a musical ability that he could tell at once when I struck the middle 'C'; then I could transmit to that person a message in the ordinary Morse code by playing on the middle 'C,' and that person, whom I shall call Mr. C, would not take any notice of the fact that I might also be playing on the notes D, E, F, G, &c., but Mr. C would confine his attention entirely to what is being done with the middle 'C.' It is conceivable that I might find a series of persons or train them so that they could each pick out and hear one note only of the piano, irrespective of what was being played on the other notes or of any other noises that were taking place. Taking an ordinary seven-octave piano and neglecting for a moment the black notes, this would give me fifty-six distinct notes on which I could transmit messages; so that, transmitting from Leicester, I might send messages simultaneously to fifty-six different towns.

The number of possible simultaneous messages depends on the number of octaves there are on the piano used, and on how close together the different notes are which can be used without producing confusion. For instance, it might be quite easy to train someone to distinguish with certainty between 'C' and 'E,' and pick out signals on 'C' at the same time that signals are being sent on 'E.' It is certainly more difficult to do this with two notes that are closer together, say 'C' and 'D,' and still more difficult if the half-tones are used as well. The problem, therefore, in wireless telegraphy is to arrange the receiving apparatus so that it can hear, or perhaps I should say, more accurately, so that it can only see, notes of one definite frequency or pitch, and not be affected by any other notes, even though of but slightly different pitch. Another requirement to obtain good working is that we should use as little power as possible at our transmitting station consistent with obtaining enough power in our receiving instruments to work them with certainty.

I have a mechanical model to illustrate how we are able to make our receiving instruments very sensitive to one frequency and only slightly affected by frequencies which differ but slightly from its proper frequency.

The transmitter in the model consists of a disc that can be rotated slowly at any speed I like, with a pin fixed eccentrically on its face. This pin can be connected to a vertical wire which moves up and down as the disc rotates. I shall assume that the movement of this wire corresponds with the movement of the electricity in the vertical conductor. As a receiving apparatus I have a pendulum, and representing the ether between the transmitter and receiver I have an elastic thread connecting the pin in the disc to the pendulum.

When I set the disc rotating slowly the elastic thread is alternately stretched out and relaxed, and the pendulum is a little affected. If I gradually increase the speed of the disc at one definite speed it will be found that the pendulum is set into violent oscillation, and by observation it will be found that when this is the case the disc makes one complete revolution in exactly the same time that the pendulum would make one complete swing if left to itself; that is to say, that the disc and the pendulum make the same number of swings per second or have the same frequency; in music they would be said to be in tune with each other. If instead of allowing the disc to rotate continuously I allow it to make only half a dozen revolutions, then the pendulum will be affected, but much less strongly. The greater the number of revolutions the disc makes up to a certain maximum number the more the pendulum will be caused to swing.

Instead of starting and stopping the disc I can keep the disc rotating and start and stop the pulls on the elastic thread by moving the pin in the face of the disc

in and out from the centre, which produces a movement which much more nearly corresponds with the actual current in the vertical wire as used in spark telegraphy.

It is necessary here to explain the relationship that exists between the wave-length, the frequency, and the velocity of propagation of Hertzian waves. The waves travel with, as far as we know, the same velocity as light—namely, 300,000,000 metres, or 186,000 miles, per second. Between these quantities we have the relationship that the product of the wave-length by the frequency is equal to the velocity of propagation, or, as I have already mentioned, the velocity of light.

The wave-lengths which are of practical use in wireless telegraphy at the present time range between 100 and 3,000 metres, though, of course, it is quite possible to use for special purposes wave-lengths outside these limits. The corresponding frequencies in practical use are therefore between 3,000,000 and 100,000 complete periods per second. We require, therefore, to produce in the vertical conductor alternating or oscillating currents of any frequency within this range, and to have a sufficient number of oscillations following one another without interruption to allow of good syntony being obtained.

There are three methods of producing these currents—namely, the alternator, the spark, and the arc methods.

There are great difficulties in the way of constructing an alternator to give such high-frequency currents, and I can best illustrate this by taking an example. Suppose that it is required to build an alternator to work at the lowest frequency, namely, 100,000 periods per second, and let us assume that we can drive this alternator by means of a turbine at the high speed of 30,000 revolutions per minute. This alternator could not have a diameter much above 6 inches for fear of bursting; and, as it makes 500 revolutions per second, it would have to generate 200 complete periods for each revolution, so that the space available for the windings and poles for one complete period will be less than $\frac{1}{10}$ inch, a space into which it is quite impossible to crush the necessary iron and copper to obtain any considerable amount of power. In spite of the small space that we have allotted to each period, as there are 100,000 periods per second, the speed of the surface of the moving part works out at over 500 miles per hour. A small alternator has been built to give over 100,000 frequency, but the amount of power it produced was extremely small. Several experimenters have stated lately that they have built alternators giving these high frequencies and a considerable amount of power, but, so far as I am aware, there is no reliable data available as to the design of these machines.

If it should prove possible to construct alternators for these very high frequencies, we shall be able to obtain a sufficient number of consecutive oscillations of the current in the aërial of definite frequency to enable very sharp syntony to be obtained. Not only will this greatly reduce interference troubles in wireless telegraphy, but such alternators will be of the greatest value for wireless telephony.

The earliest method of producing high-frequency oscillations was proposed by Lord Kelvin, who pointed out that if a Leyden jar or condenser be allowed to discharge through a circuit possessing self-induction or electrical inertia, then under certain conditions the discharge of the jar is oscillatory, that is to say, that the electricity flows backwards and forwards in the circuit several times before the jar or condenser becomes finally discharged. I think that perhaps the best way to make this matter clear is by demonstrating experimentally with an oscillograph the nature of the discharge of a condenser, and how it is affected by the resistance and self-induction in the circuit. As a mechanical analogy one may look upon the charged condenser as a weight attached to a spring which has been pulled away from its position or rest. To discharge the condenser we let go the weight and it begins to oscillate backwards and forwards, and, after making a greater or less number of oscillations, finally comes to rest. The number of oscillations per second will depend upon the strength of the spring and the mass of the weight, which correspond with the capacity and self-induction in our electrical circuit. The number of oscillations before the weight finally comes to rest is

determined by the friction which tends to stop the weight, or by the resistances and other losses in the electrical circuit.

In practice the aërial conductor acts as a Leyden jar or condenser. It is charged with electricity and allowed to discharge, the current oscillating backwards and forwards in the aërial during the discharge. In many installations Leyden jars or condensers are electrically connected to the aërial, so that the oscillations taking place in them are transmitted to the aërial. Any remarks, therefore, that I may make as to the oscillations which may be set up in condensers apply equally well to the oscillations in the aërial in wireless telegraphy.

For wireless telegraphy it is usual to charge the condenser or aërial by means of an induction coil or an alternator to a very high voltage, and it is allowed to discharge by means of a spark between the two electrodes which form the ends, so to speak, of a gap in the electrical circuit. As long as the pressure is low the spark gap is a perfect insulator; when the pressure becomes high enough the air between the electrodes breaks down and a spark passes the gap, becomes conducting, and allows the condenser to discharge. The property of the spark-gap of passing almost instantaneously from a condition of being an insulator for electricity to being an extremely good conductor for electricity is of the utmost value in the spark method of wireless telegraphy. The more perfectly the spark-gap is insulated before the discharge takes place, and the more perfectly it conducts after the discharge has taken place, the better it is for our purpose.

If I take two electrodes sufficiently far apart in air and gradually raise the electrical pressure between them, the first indication that anything is going to happen is the formation of fine violet aigrette on the more pointed or rougher parts of the electrodes. This is known as the brush discharge. By gradually raising the pressure, this brush discharge extends further out into the air, until finally the air between the two electrodes becomes so strained that it breaks down and the real spark passes.

The long thin spark that occurs in this case is not very suitable for wireless telegraphy, as its resistance is too high. Ordinary lightning flashes are good examples of long sparks on a very large scale. If instead of working with the electrodes far apart they are placed nearer together, and if the electrical pressure is supplied from a very powerful source, then directly the spark passes it forms a thick discharge having the appearance of a flame in which the nitrogen of the air is actually being burnt; a process which, it is hoped, in the future may have immense importance in the supply of artificial nitrates for agriculture. This flame-like discharge has a low electrical resistance, but has the effect that it so heats or modifies the air that it is difficult to get the air to insulate again, after one discharge, ready for the next.

If a large quantity of electricity is discharged through the spark-gap, and if the spark lasts a very short time compared with the interval between successive sparks, then a highly conducting spark can be obtained, as well as a good insulation between the sparking terminals when no discharge is passing.

In order to help to bring the gap back to its insulating condition after each discharge, many devices are employed, such as subdividing the spark into several shorter sparks, cooling the electrodes, blowing air across the spark-gap, &c. When the condenser, or antenna, discharges through the spark-gap, oscillations are set up which radiate Hertzian waves.

In practice in wireless telegraphy it is difficult to obtain a large number of oscillations during each discharge as corresponding with each oscillation; the antenna radiates energy. A large number of oscillations means, if we keep amplitude of each the same, that we are radiating a large quantity of energy. Besides this radiated energy, which is useful for transmitting messages, there is also energy wasted in heat in the spark-gap, in the conductors, in the glass or other insulation of the condensers. It is this useless part which we require to make as small as possible.

I have lately had an opportunity to determine how many oscillations actually take place in a certain wireless transmission. The experiment was made by photographing the spark as seen in a mirror rotated at a very high speed, and it was found that each spark consisted of nine or ten complete oscillations.

If all the oscillations had been of equal strength or amplitude, and if the receiving circuit had been similar to my pendulum in my mechanical model, then there would be very little to be gained by increasing the number of oscillations. As the oscillations die away in the spark method, two or three times this number would probably be required for the best effect. As a matter of experiment very good tuning was obtained with the wireless transmission referred to above.

As an example of the sharpness of tuning obtainable by the spark method the following test carried out on the Lodge-Muirhead installation at Hythe may be of interest.

The station at Hythe had to receive messages from Elmers End at a distance of 58 miles over land, in spite of the fact that the Admiralty station at Dover, only $9\frac{1}{4}$ miles distant, was transmitting as powerfully as it could, in order to produce interference, and that the regular communications were going on in the Channel between the shipping. It was found possible with a difference of wave-length of 6 per cent. to cut out the interference from the Dover station.

In the arc method of producing continuous oscillations we employ, as before, a condenser and self-induction; but, instead of charging the condenser to a high voltage and allowing it to discharge by means of oscillations which die away, and then repeating the process over and over again, we actually maintain the condenser charging and discharging continuously without any intermission, so that we practically obtained a high-frequency alternating current in the aërial.

To impress the difference on your minds, I have an incandescent lamp, which I switch on and off rapidly about ten times, and then after a short time I repeat the same flickering of the light, and so on. The flickering of the light corresponds with the oscillations in the ordinary spark method, and the time spaces between the flickers represent the times during which the condenser or antenna is being charged ready to produce a fresh series of oscillations. In practice we may have as many as, say, a couple of hundred discharges of the condenser a second, and during each discharge we may get, say, ten complete oscillations, each oscillation lasting one millionth of a second, if the wave-length is 300 metres; thus the total time that the condenser is discharging is only one one-hundred-thousandth of a second, or one five-hundredth part of the interval of time between two successive discharges. My lamp here flickers about five times per second, and makes ten flickers before it goes out; the total time that it is flickering is two seconds, and the time before it should start to flicker again to correspond with the practical wireless case is therefore 1,000 seconds, or rather over a quarter of an hour. If now I represent continuous oscillations, such as are obtained by the arc method with this lamp, I shall simply keep the lamp flickering continuously, and there will be no intervals whatever.

The arc method of producing continuous oscillations is founded on my musical arc. In order to explain this I must demonstrate some of the properties of the direct-current arc. If I vary the current flowing through the arc very slowly and note the potential difference corresponding with each value of the current, keeping everything else constant, I obtain a curve generally spoken of as the characteristic of the arc. These curves under different conditions have been very thoroughly investigated by Mrs. Ayrton.

With the carbon arc between electrodes in air the voltage decreases very rapidly when the current is gradually increased, starting from very low values. As the current becomes larger the rate of decrease of the voltage becomes less and less until it is, comparatively speaking, quite small, with a current of 10 or 12 amperes. With the arc between metal electrodes similar results are obtained, except that the discontinuity in the curves, called the hissing point by Mrs. Ayrton, takes place at very small currents, generally well below an ampere.

With arcs burning in hydrogen, Mr. Upson has found that the curves are generally much steeper for the larger values of the current than for the corresponding arcs burning in air. This point is of great importance as explaining the value of the hydrogenic atmosphere used by Poulsen and referred to later.

In general, I may therefore say for the above arcs that increase in current through the arc is accompanied by decrease of the potential difference between its

electrodes, and *vice versâ* decrease of the current causes increase in the potential difference; on the other hand certain arcs, such as the arc between cored carbons, behave in an opposite manner, that is to say, current and potential difference increase and decrease together.

I demonstrated in 1900 that if I connect between the electrodes of a direct current arc (or other conductor of electricity for which an increase in current is accompanied by a decrease in potential difference between the terminals) a condenser and a self-induction connected in series, I obtain in this shunt circuit an alternating current. I called this phenomenon the musical arc. The frequency of the alternating current obtained in this shunt circuit depends on the value of the self-induction and the capacity of the condenser, and may practically be calculated by Kelvin's well-known formula.

Besides the condition that an increase of current must be accompanied by a decrease in potential difference, it is necessary that the relative decrease in potential difference produced by a given increase in current, that is to say, the steepness of the characteristic, shall exceed a certain minimum value which depends on the losses in the shunt circuit. It is also necessary that an increase in current shall be accompanied by a decrease in potential difference, even when the current is varied very rapidly.

Let us consider what takes place when I connect this shunt circuit to an arc. At the moment of connection a current flows from the arc circuit into the condenser circuit, which tends to reduce the current flowing through the arc. This reduction of the current through the arc tends to raise the potential difference between its terminals, and causes still more current to flow into the condenser circuit, and I now have a condenser charged above the normal voltage of the arc. The condenser, therefore, begins to discharge through the arc, which increases the arc current and decreases the potential difference, so that the condenser discharges too much; the reverse process then sets in; the condenser becomes successively overcharged and undercharged, due to the fact that, instead of the potential difference between the terminals of the arc remaining constant and allowing the condenser to settle down with its proper corresponding charge, the potential difference actually decreases when the condenser is discharged and increases when it is charging, so as to help to keep up the flowing backwards and forwards of the current indefinitely.

The oscillograph wave forms show what is going on very clearly, and they show that in general the swing of the current in the condenser circuit attains such a magnitude that when the condenser is charging it takes the whole of the current away from the arc, so as to make the arc, although burning on a direct current, a pulsatory arc. The pulsation of the current through the arc causes the vapour column to grow bigger and smaller, and the light to vary. When the vapour column grows bigger and smaller it displaces the air around it and produces a note the pitch of which is determined by the frequency of the current in the shunt circuit.

The values of the capacities of a series of condensers have been calculated by Kelvin's formula to give the frequencies corresponding with a musical octave, and the nearest values in an ordinary laboratory box of condensers have been taken and connected to a keyboard. The result shows how nearly Kelvin's law is obeyed.

With this apparatus I can demonstrate the importance of tuning in electrical circuits and perform electrically some experiments which I have already performed mechanically earlier this evening. I use the large coil which forms the self-induction in the circuit shunting the arc as a transmitting circuit for wireless telegraphy by the magnetic induction or Preece method, and I have a receiving circuit consisting of a coil of wire connected to a small lamp and not connected in any way to the transmitting circuit. At a certain short distance between the transmitting coil and the receiving coils the indicating lamp lights if I cause my arc to sound *any* one of the notes of the octave, and so produce an alternating current of corresponding frequency in the transmitting coil. If I now tune the receiving circuit, by connecting a condenser in it, the lamp on the receiving circuit

will light at about five times the distance; but it will only light when one definite note is sounded by the arc. These are the two distinct advantages of tuning, namely, greater distance and syntony, or responding to only one definite note.

For wireless telegraphy by means of Hertzian waves, based on my arc method, we require much higher frequencies in the shunt circuit. If we attempt to obtain this higher frequency from the ordinary arc burning between solid carbons in air, we find that above a certain limit the oscillations will no longer take place. This is due to the fact that we are varying the current through the arc at this higher frequency too quickly for an increase in current to be accompanied by a decrease in potential difference. I have demonstrated that if I only vary the current through the ordinary current arc sufficiently rapidly, then an increase in current is accompanied by a proportionate increase in the potential difference, and the arc behaves just like an ordinary resistance. If we work with very small current arcs we can obtain high-frequency musical arcs burning in air either between carbon or metal electrodes.

In a paper read before the International Electrical Congress at St. Louis in 1904 Mr. Poulsen showed that by placing the arc in a flame it was possible to obtain higher frequencies than when the arc was burning in air. Following this up Mr. Poulsen came to the conclusion that the best results were obtained when the arc was burning in hydrogen, or a gas containing hydrogen; and he further added a magnetic field around the arc somewhat similar to that which has been previously used by Elihu Thomson.

The arc burning in coal gas in a powerful transverse magnetic field was used by Poulsen in his early experiments to produce the high-frequency current necessary for wireless telegraphy between Lyngby and Esbjerg in Denmark. This apparatus has been further improved, and is now employed by the Amalgamated Radio-Telegraph Company in their station at Cullercoats and the other stations that they are erecting.

In both the arc and the spark methods of wireless telegraphy we employ a high-frequency alternating current in the aërial conductor. The essential difference between the two methods lies in the fact that with the spark method our alternating current in the aërial conductor first increases to a maximum value and then dies away rapidly, making only a limited number of oscillations, whereas in the arc method the oscillations are maintained continuously of unvarying amplitude.

With the arc method we are further able to choose the number of consecutive oscillations which make up each signal sufficiently great to obtain the very best syntony. On the other hand, improvement in the arrangement and construction of the apparatus for the spark method has so increased the number of oscillations corresponding with each spark that it may be that we shall be able to obtain a sufficient number in each train to give as good syntony by this method as that obtained with the arc method.

The arc method seems eminently suitable for very high speeds of working. As the oscillations are quite continuous, we can cut them up into groups to form the dots and dashes of the Morse alphabet, just as if we were working with a continuous current such as is used on land lines, so that there seems no reason why as high a speed of working should not be obtained from the arc method of wireless telegraphy as is obtainable by automatic signalling on land lines; for it is to be noted that the dot or shortest signal of the Morse alphabet, even at a speed of three or four hundred words per minute, will last long enough to consist of many hundreds of oscillations of the current in the aërial, so that there will be plenty of oscillations in the group forming the dot to give good syntony.

Turning to the spark method for high working speeds, we find a difficulty in that the dot of the Morse alphabet must at least occupy the average time required to charge the condenser or aërial and produce one spark, and preferably sufficiently long for several. We are therefore obliged in the spark method to use a high rate of sparking for high-speed signalling. This difficulty has not become very serious with the present low speeds of sending. When we come to use considerable amounts of power to transmit messages over long distances, and we also require a high speed of working, the practical difficulty in constructing apparatus suitable for sufficiently rapid sparking will become serious.

Mr. Marconi in 1905 claimed to have already reached a speed of a hundred words per minute by the spark method, and lately there has appeared in the technical press examples of high-speed signalling by the British Post Office over a distance of 15 miles in which readable signals were received at a speed of seventy words per minute.

Turning to the receiving end, almost all the receivers that have been used in the spark method can be equally well used for the arc method; for it must be remembered that the transmission in either case is affected by Hertzian waves traversing space, and that the only fundamental difference consists in the number of oscillations in each train of waves. It must be noted, however, that in those methods in which a telephone receiver is used it is necessary to break up the continuous oscillations of the arc method into groups succeeding one another sufficiently rapidly to produce an audible sound in the receiver; for in the spark method the sounds we hear in the receiver correspond with the succession of impulses of the diagram, one for each spark at the transmitter. This chopping up of the continuous wave-train so as to produce audible signals in the receiving apparatus can be done either at the transmitting end or in the receiving apparatus. An example of this latter method is Poulsen's ticker.

The question whether receiving apparatus can be arranged so as to receive messages from stations equipped with the spark apparatus and from stations equipped with the arc apparatus is a matter of enormous importance at the present moment in view of the probable ratification of the Berlin Convention, which imposes an obligation on all commercial stations to intercommunicate without regard to the make or system of transmitting apparatus employed. I am of the opinion that there will be no difficulty in carrying this into effect provided that the stations using the spark method send out long trains of waves, as they should do to obtain syntonic working, which is also called for by the Berlin Convention.

An extremely interesting development which is now progressing rapidly, owing to the possibility of producing continuous oscillations by the arc method, is wireless telephony. Suppose that we can vary the intensity of the oscillations in a manner corresponding with the vibrations of the air which constitutes sound and speech, then we should obtain at the receiving stations a train of Hertzian waves whose amplitude varies in a corresponding way; by allowing these waves to act on a telephonic receiver which is sensitive to the intensity of the waves we shall obtain in the telephone a reproduction of the sounds. This has actually been carried into effect by employing an ordinary microphone to modify the current through the transmitting arc so as to vary the intensity of the oscillation current produced, and by employing what is known as a point-detector and a telephone at the receiving station.

Another method which may be used consists in causing the microphone to vary the frequency of the oscillations of the generator, and by arranging the receiver so that it is more or less strongly affected according to the frequency of the received waves.

I am informed that such good results have already been obtained on the experimental stations for wireless telephony that it is proposed to equip stations at Oxford and Cambridge for the further perfecting of this application.

It is greatly to be desired that wireless telephony may develop rapidly, as it seems to me that for the purpose of communicating with ships wireless telephony will have great advantages over wireless telegraphy.

I am deeply indebted to Mr. Colson for all the facilities that he has placed at my disposal, and to his engineers for their assistance, which has enabled me to carry out the experiments in the lecture; and I have also to thank the Tramway Department for the special supply of current.

MONDAY, AUGUST 5.

Recent Developments in the Theory of Mimicry. *By* F. A. Dixey, *M.A., M.D.*

The remarkable resemblances that exist between certain insects belonging to widely different orders, as, for instance, the likeness borne by some of the 'clearwing moths' to wasps and hornets, have long been known to naturalists. They were interpreted by the older observers as cases of 'repetition' and 'analogy' in Nature. Kirby and Spence were the first to attempt a rational explanation. These authors got so far as to suggest that one species might gain an advantage by resembling another; but the first really scientific account of the matter was given by Bates, who pointed out that certain kinds of butterflies in South America escaped attacks from birds by mimicking the appearance of other conspicuous species which were immune from persecution on account of the possession of distasteful qualities. This resemblance to a distasteful model he considered had been gained by a gradual selection of varieties tending in the appropriate direction.

Bates's theory of mimicry, which was at once accepted by Darwin and met with general approval, marked an important step in advance. It left, however, unexplained the fact that these resemblances occurred, not only between distasteful models and their presumably edible mimics, but also between the distasteful models themselves. To account for this he could only suggest that there must be something in the local or geographical conditions which had a direct effect upon forms inhabiting the same region, causing them, even if widely separated in affinity, to assume a common aspect.

But the existence of large groups of insects with various affinities and a common facies was felt as a stumbling-block in the way of the theory of mimicry until in 1879 Fritz Müller found the key to unlock the difficulty. He showed that if (as experiments, chiefly by Lloyd Morgan, have subsequently proved to be the case) birds had no instinctive knowledge of what forms would be suitable for food and what should be avoided, so that each bird had to gain its knowledge by experience, a certain number of the distasteful forms would have to be sacrificed by each generation of birds until these enemies had learned to leave such forms alone. In other words, each distasteful form would have to pay a tax for its immunity. Now if two distasteful species resembled each other so closely that birds or other enemies did not distinguish between them, the disagreeable experience gained by tasting an individual of one species would be applied to the benefit of the other, and so each of the two species would only need to contribute a portion of the tax, instead of each paying the whole. And what is true of a combination of two species would be equally true of a larger assemblage: the greater number of forms that could be got to share the tax, the better for all. Hence the formation of these large Müllerian groups, or, as they might be called, 'inedible associations,' giving room, no doubt, for a certain amount of Batesian mimicry side by side with them or within their own ranks. It is obvious that the resemblances shown between members of these groups, constituted as they are by insects of widely separated orders, cannot be explained by affinity; while the fact (amongst others) that the resemblances are superficial only, never structural, makes strongly against the view which would attribute them to the direct operation of external conditions. The Müllerian theory, which is rather a theory of common warning marks, or 'synaposematism' (Poulton), than of mimicry proper, may thus be said to hold the field as meeting the facts to an extent of which no alternative explanation has been found capable. Müller's suggestion was first brought to the notice of British naturalists by Professor Meldola; and in its futher developments at the hands of Meldola himself and of Poulton, it was accepted both by Wallace and by Trimen, the two naturalists who had done most by their own observations to confirm the validity of the original theory of Bates. It is to be observed that both theories alike postulate the operation of natural selection.

It seemed desirable to seek for further confirmation of the truth of Fritz Müller's interpretation, and this the lecturer has made it his business to do. It appeared to him that if the Müllerian theory were valid, certain consequences ought to follow. Did these consequences follow or did they not?

(1) It is obvious that in Batesian or true mimicry the advantage is all on the side of the mimic. Experience gained by tasting the mimic would be used to the injury of the model. While therefore there is every inducement for the mimic to seek safety by approaching nearer and nearer to the aspect of the model, there is no reason for the model to assimilate itself to the mimic, but rather the contrary.

In a Müllerian association, on the other hand, the benefit is mutual. Each fresh accession to the group is a source of strength, not of weakness. Everything is in favour of the formation of such groups as rapidly and on as large a scale as possible; hence there is nothing to impede, and everything to promote, the free interchange of characters all round, each member being able to act, so to speak, as both mimic and model. This could not happen, as has been shown, in the case of Batesian mimicry.

Several instances of such reciprocity or interchange of features have been detected by the lecturer, and others have since come to light. From what has gone before, it is clear that such cases, inexplicable on any other theory, tend to establish the validity of the Müllerian hypothesis.

(2) A further consequence of the mutual influence exercised by the constituents of a Müllerian group is this: it ought sometimes to happen that two species, though both influenced in common by a third, will show a nearer approach to each other than either does to the common model. As a matter of fact this is found actually to occur in Nature, and fresh evidence is thus supplied for the validity of the Müllerian interpretation. This phenomenon, again, could not happen in Batesian mimicry. Two true or Batesian mimics of the same model could not influence each other; they could only be influenced in common by their model.

(3) Finally, the fact that each distasteful form is capable of affording protection to forms on each side of it may be expected to favour the existence of gradational groups; distasteful forms, with perhaps little or no resemblance between them, being held together, as it were, by a chain of distasteful intermediates. This also has been found to be the case, many of the mimetic groups in a given zoological region forming together a kind of nexus, each node of which may be occupied by a dominant group or species showing a very different colour-scheme from the occupants of the other nodes, while the uniting strands of the network are constituted by a more or less completely gradated series of transitional forms.

It will be seen from the foregoing how far we have advanced beyond the original conception of Bates, and it must be allowed to be a striking fact that the progress of recent investigation has uniformly tended to supply fresh confirmation of those developments of the theory of mimicry which have traced their origin from the fertile suggestion of Fritz Müller.

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
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1903. ‡AUSTIN, CHARLES E. 37 Cambridge-road, Southport.
1853. *AVEBURY, The Right Hon. Lord, D.C.L., F.R.S. (PRESIDENT, 1881; TRUSTEE, 1872– ; Pres. D, 1872; Council, 1865–71.) High Elms, Farnborough, Kent.
1877. *AYRTON, W. E., F.R.S. (Pres. A, 1898; Council 1889–96), Professor of Electrical Engineering in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 41 Norfolk-square, W.

1900. ‡BACCHUS, RAMSDEN (Local Sec. 1900). 15 Welbury-drive, Bradford.
1883. *Bach, Madame Henri. 19 Avenue Bosquet, Paris.
1906. §Backhouse, James. Daleside, Scarborough.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1903. ‡Baden-Powell, Major B. 22 Prince's-gate, S.W.
1907. §Badgley, Colonel W. F., Assoc.Inst.C.E., F.R.G.S. Verecroft, Devizes.
1905. §Baikie, Robert. P.O. Box 36, Pretoria, South Africa.
1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1883. *Bailey, Charles, F.L.S. Atherstone House, North-drive, St. Anne's-on-the-Sea, Lancashire.
1893. ‡BAILEY, Colonel F., F.R.G.S. 7 Drummond-place, Edinburgh.
1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
1905. *Bailey, Harry Percy. 22 Clarendon-road, Margate.
1905. §Bailey, W. F., C.B. Land Commission, Dublin.
1894. *BAILY, FRANCIS GIBSON, M.A. Newbury, Colinton, Midlothian.
1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
1897. §BAIN, JAMES. Public Library, Toronto, Canada.
1905. §Baker, Sir Augustine. 56 Merrion-square, Dublin.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1907. §Baldwin, Walter. 5 St. Alban's-street, Rochdale.
1904. ‡BALFOUR, The Right Hon. A. J., D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. (PRESIDENT, 1904.) Whittinghame, Prestonkirk, N.B.
1894. ‡BALFOUR, HENRY, M.A. (Pres. H, 1904). 11 Norham-gardens, Oxford.
1905. ‡Balfour, Mrs. H. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1894; K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1905. ‡Balfour, Mrs. J. Dawyck, Stobo, N.B.
1905. ‡Balfour, Lewis. 11 Norham-gardens, Oxford.

Year of Election.

1905. ‡Balfour, Miss Vera B. Dawyck, Stobo, N.B.
1878. *Ball, Sir Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *Ball, Sir Robert Stawell, LL.D., F.R.S., F.R.A.S. (Pres. A, 1887; Council, 1884–90, 1892–94; Local Sec. 1878), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1908. §Ball, T. Elrington. 6 Wilton-place, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1905. ‡Ballantine, Rev. T. R. Tirmochree, Bloomfield, Belfast.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, M.Sc. 30 Falkland-mansions, Glasgow.
1899. §Bampton, Mrs. 42 Marine-parade, Dover.
1905. §Banks, Miss Margaret Pierrepont. 10 Regent-terrace, Edinburgh.
1898. ‡Bannerman, W. Bruce, F.S.A. The Lindens, Sydenham-road, Croydon.
1890. *Barber-Starkey, W. J. S. Aldenham-park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1902. ‡Barcroft, H., D.L. The Glen, Newry, Co. Down.
1902. ‡Barcroft, Joseph, M.A., B.Sc. King's College, Cambridge.
1904. §Barker, B. T. P. Fenswood, Long Ashton, Bristol.
1906. *Barker, Geoffrey Palgrave. Henstead Hall, near Wrentham, Suffolk.
1899. §Barker, John H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1882. *Barker, Miss J. M. The Fox Covers, Bebington, Cheshire.
1898. ‡Barker, W. R. 106 Redland-road, Bristol.
1889. ‡Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
1883. ‡Barlow, J. J. 84 Cambridge-road, Southport.
1885. *Barlow, William, F.G.S. The Red House, Great Stanmore.
1905. §Barnard, Miss Annie T., M.D., B.Sc. 32 Chenies-street-chambers, Gower-street, W.C.
1902. §Barnard, J. E. Park View, Brondesbury Park, N.W.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1904. ‡Barnes, Rev. E. W., M.A., F.R.A.S. Trinity College, Cambridge.
1907. §Barnes, H. T. Heys Bungalow, Glan Conway, North Wales.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E., Professor of Civil Engineering in the University, Glasgow.
1902. *Barr, Mark. The Cedars, Cowley, Middlesex.
1904. ‡Barrett, Arthur. 6 Mortimer-road, Cambridge.
1872. *Barrett, W. F., F.R.S., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1893. *Barrow, George, F.G.S. 28 Jermyn-street, S.W.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. Falcon Hall, Edinburgh.

Year of Election.

1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1893. *Barton, Edwin H., D.Sc., F.R.S.E., Professor of Experimental Physics in University College, Nottingham.
1904. *Bartrum, C. O., B.Sc. 12 Heath-mansions, Heath-street, Hampstead, N.W.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, N.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. (Pres. F, 1894). 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. 8a Manchester-square, W.
1883. ‡Bateman, Sir A. E., K.C.M.G. Woodhouse, Wimbledon Park, S.W.
1907. §Bateman, Harry. Trinity College, Cambridge.
1884. ‡Bateson, William, M.A., F.R.S. (Pres. D, 1904). St. John's College, Cambridge.
1881. *Bather, Francis Arthur, M.A., D.Sc., F.G.S. British Museum (Natural History), S.W.
1906. §Batty, Mrs. Braithwaite. Ye Gabled House, The Parks, Oxford.
1863. §Bauerman, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1904. ‡Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1905. ‡Baxter, W. Duncan. P.O. Box 103, Cape Town.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
1905. *Bazley, Miss J. M. A. Kilmorie, Ilsham-drive, Torquay, Devon.
Bazley, Sir Thomas Sebastian, Bart., M.A. Kilmorie, Ilsham-drive, Torquay, Devon.
1889. §Beare, Professor T. Hudson, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1905. §Beare, Mrs. T. Hudson. 10 Regent-terrace, Edinburgh.
1904. §Beasley, H. C. 25a Prince Alfred-road, Wavertree, Liverpool.
1905. ‡Beattie, Professor J. C., D.Sc., F.R.S.E. South African College, Cape Town.
1902. ‡Beatty, H. M., LL.D. Ballymena, Co. Antrim.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1900. ‡Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. The Laboratory, Citadel Hill, Plymouth.
1885. *Beaumont, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C.
1887. *Beckett, John Hampden. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. The Schoolhouse, Whitchurch, Salop.
1885. ‡Beddard, Frank E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. ‡Beddoe, John, M.D., F.R.S. (Council, 1870–75). The Chantry, Bradford-on-Avon.
1904. *Bedford, T. G., M.A. 9 Victoria-street, Cambridge.
1891. ‡Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡Bedson, P. Phillips, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.

Year of Election.

1901. *BEILBY, G. T., F.R.S. (Pres. B, 1905.) 11 University-gardens, Glasgow.
1905. ‡Beilby, Hubert. 11 University-gardens, Glasgow.
1891. *Belinfante, L. L., M.Sc., Assist. Sec. G.S. Burlington House, W.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. British Museum, S.W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1900. *Bell, H. Wilkinson. Holmehurst, Rawdon, near Leeds.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. 52 Cromwell-road, Hove, Brighton.
1871. *BELL, J. CARTER, F.C.S. The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1905. ‡Bell, W. H. S. P.O. Box 4284, Johannesburg.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1904. ‡Bellars, A. E. Magdalene College, Cambridge.
1905. ‡Bender, Rev. A. P., M.A. Synagogue House, Cape Town.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. ‡Bennett, Professor Peter. 6 Kelvinhaugh-street, Sandyford, Glasgow.
1905. §Benson, Arthur H., M.A., F.R.C.S. 42 Fitzwilliam-square, Dublin.
1905. §Benson, Mrs. A. H. 42 Fitzwilliam-square, Dublin.
1903. §Benson, D. E. Queenwood, 12 Irton-road, Southport.
1901. *Benson, Miss Margaret J., D.Sc. Royal Holloway College, Egham.
1887. *Benson, Mrs. W. J. Care of Johannesburg Consolidated Investment Co., P.O. Box 590, Johannesburg, Transvaal.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1904. ‡Bentley, B. H. The University, Sheffield.
1905. §Bentley, F. W. Rein Wood, Huddersfield.
1905. *Bentley, W. C. Rein Wood, Huddersfield.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §BERKELEY, The Earl of, F.G.S. Foxcombe, Boarshill, near Abingdon.
1905. *Bernacchi, L. C., F.R.G.S. Pound Farm, Surbiton, Surrey.
1906. *Bernays, Albert Evan. 3 Priory-road, Kew, Surrey.
1898. §Berridge, Miss C. E. 7 Albert-mansions, Lansdowne-road, Croydon.
1894. §BERRIDGE, DOUGLAS, M.A., F.C.S. The College, Malvern.
1904. §Berry, R. A. West of Scotland Agricultural College, 6 Blythswood-square, Glasgow.
1905. §Bertrand, Captain Alfred. Champel, Geneva.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1880. *BEVAN, Rev. JAMES OLIVER, M.A., F.S.A., F.G.S. Chillenden Rectory, Dover.
1904. *Bevan, P. V., M.A. Garden-walk, Chesterton, Cambridge.
1906. §Bevan-Lewis, W., M.D. West Riding Asylum, Wakefield.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1903. ‡Bickerdike, C. F. 1 Boverney-road, Honor Oak-park, S.E.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1885. *BIDWELL, SHELFORD, Sc.D., LL.B., F.R.S. Beechmead, Oatlands Chase, Weybridge.
1904. §Bigg-Wither, Colonel A. C. Tilthams, Godalming, Surrey.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion-hill, S.E.
1898. ‡Billington, Charles. Heimath, Longport, Staffordshire.
1901. *Bilsland, William, J.P. 28 Park-circus, Glasgow.
1887. *Bindloss, James B. Elm Bank, Buxton.
1884. *Bingham, Colonel Sir John E., Bart. West Lea, Ranmoor, Sheffield.

Year of Election.

1881. ‡BINNIE, Sir ALEXANDER R., M.Inst.C.E., F.G.S. (Pres. G, 1900.) 77 Ladbroke-grove, W.
1887. *Birley, H. K. Penrhyn, Irlams o' th' Height, Manchester.
1904. §Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1906. §Bishop, J. L. Inland Revenue Office, York.
1894. ‡Bisset, James, F.R.S.E. 9 Greenhill-park, Edinburgh.
1886. *Bixby, Colonel W. H. Room 501, Federal-building, Chicago, U.S.A.
1905. ‡Black, Alexander. 43 Castle-street, Cape Town.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1903. *BLACKMAN, F. F., M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1902. ‡Blake, Robert F., F.I.C. 66 Malone-avenue, Belfast.
1894. ‡*Blakiston, Rev. C. D. Exwick Vicarage, Exeter.*
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1905. ‡Blamires, Mrs. Bradley Lodge, Huddersfield.
1904. ‡Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., M.A., B.Sc. The University, Glasgow.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. ‡Bloxsom, Martin, B.A., M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
1901. §BLYTHSWOOD, The Right Hon. Lord, LL.D., F.R.S. Blythswood, Renfrew.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. ‡BODINGTON, Principal N., Litt.D. Yorkshire College, Leeds.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §BOLTON, H., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §BOLTON, JOHN. 15 Cranley-gardens, Highgate, N.
1898. *BONAR, JAMES, M.A., LL.D. (Pres. F, 1898; Council, 1899–1905.) The Mint, Ottawa, Canada.
1871. *BONNEY, Rev. THOMAS GEORGE, D.Sc., LL.D., F.R.S., F.S.A., F.G.S. (SECRETARY, 1881–85; Pres. C, 1886.) 9 Scroope-terrace, Cambridge.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *BOOTH, Right Hon. CHARLES, D.Sc., F.R.S., F.S.S. 24 Great Cumberland-place, W.
1883. ‡Booth, James. Hazelhurst, Turton.
1908. §Booth, Robert, J.P. Bartra Hall, Dalkey, Co. Dublin.
1876. ‡Booth, Rev. William H. St. Paul's Rectory, Old Charlton, Kent.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1901. *Boothroyd, Herbert E., M.A., B.Sc. Sidney Sussex College, Cambridge.
1882. §BORNS, HENRY, Ph.D., F.C.S. 5 Sutton Court-road, Chiswick, W.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
1876. *BOSANQUET, R. H. M., M.A., F.R.S., F.R.A.S. Castillo Zamora, Realejo-Alto, Teneriffe.
1903. §Bosanquet, Robert C., M.A., Professor of Classical Archæolog in the University of Liverpool. Institute of Archæology, 40 Bedford-street, Liverpool.

Year of
Election.

1896. ‡Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
1881. §BOTHAMLEY, CHARLES H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Tanglewood, Southside, Weston-super-Mare.
1872. ‡Bottle, Alexander. 4 Godwyne-road, Dover.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany in King's College, W.C.
1905. §BOULENGER, G. A., F.R.S. (Pres. D, 1905.) 8 Courtfield-road, S.W.
1905. §Boulenger, Mrs. 8 Courtfield-road, S.W.
1903. §Boulton, W. S., B.Sc., F.G.S., Professor of Geology in University College, Cardiff. 26 Arches-road, Penarth.
1883. ‡BOURNE, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.
1893. *BOURNE, G. C., M.A., D.Sc., F.L.S. (Council, 1903- ; Local Sec., 1894), Linacre Professor of Comparative Anatomy in the University of Oxford. Savile House, Mansfield-road, Oxford.
1904. *Bousfield, E. G. P. Hungate Mills, York.
1902. ‡Bousfield, Sir William. 20 Hyde-park-gate, W.
1884. ‡BOVEY, HENRY T., M.A., F.R.S., M.Inst.C.E., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898; Council, 1900-06), Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Seal, Sevenoaks.
1856. *Bowlby, Miss F. E. 4 South Bailey, Durham.
1898. §BOWLEY, A. L., M.A. (Pres. F, 1906; Council, 1906- .) Northcourt-avenue, Reading.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1899. *Bowman, Herbert Lister, M.A., F.G.S. Greenham Common, Newbury.
1899. *Bowman, John Herbert. Greenham Common, Newbury.
1887. §Box, Alfred Marshall. Care of the Lancashire and Yorkshire Bank, Huddersfield.
1895. *BOYCE, Sir RUBERT, M.B., F.R.S., Professor of Pathology in the University of Liverpool.
1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.
1884. *Boyle, R. Vicars, C.S.I. 3 Stanhope-terrace, Hyde Park, W.
1892. §BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903; Council, 1893-99, 1905- .) 27 The Grove, Boltons, S.W.
1905. §Boys, Mrs. C. Vernon. 27 The Grove, Boltons, S.W.
1872. *BRABROOK, Sir EDWARD, C.B., F.S.A. (Pres. H, 1898; Pres. F, 1903; Council, 1903- .) 178 Bedford-hill, Balham, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Helena, Alan-road, Wimbledon, S.W.
1905. ‡Bradford, Wager. P.O. Box 5, Johannesburg.
1893. §Bradley, F. L. Ingleside, Malvern Wells.
1904. *Bradley, Gustav. Town Hall, Leigh, Lancashire.
1899. *Bradley, J. W., Assoc.M.Inst.C.E. Westminster City Hall, Charing Cross-road, W.C.
1903. *Bradley, O. Charnock, D.Sc., M.D., F.R.S.E. Royal Veterinary College, Edinburgh.
1892. ‡Bradshaw, W. Carisbrooke House, The Park, Nottingham.

Year of Election.

1863. ‡Brady, George S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1905. §Brakhan, A. P.O. Box 4249, Johannesburg.
1906. §Branfield, Wilfred. 5 Victoria-villas, Upperthorpe, Sheffield.
1885. *Bratby, William, J.P. Alton Lodge, Lancaster Park, Harrogate.
1905 §Brausewetter, Miss. Roedean School, near Brighton.
1905. ‡Bremner, R. S. Westminster-chambers, Dale-street, Liverpool.
1905. ‡Bremner, Stanley. Westminster-chambers, Dale-street, Liverpool.
1902. *Brereton, Cloudesley. Briningham House, Briningham, S.O., Norfolk.
1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
1882. ‡Bretherton, C. E. 26 Palace-mansions, Addison Bridge, W.
1905. §Brewis, E. 27 Winchelsea-road, Tottenham, N.
1907. *Bridge, Henry Hamilton. Union Club, Trafalgar-square, S.W.
1886. §Bridge, T. W., M.A., D.Sc., F.R.S., Professor of Zoology in the University of Birmingham.
1870. *Brigg, John, M.P. Kildwick Hall, Keighley, Yorkshire.
1906. §Briggs, John, M.A., F.Z.S. 32 Red Lion-square, W.C.
1904. *Briggs, William, M.A., LL.D., F.R.A.S. Burlington House, Cambridge.
1905. ‡Brill, J., Litt.D. Grey College, Bloemfontein, South Africa.
1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. The Hoppet, Little Baddow, Chelmsford.
1904. ‡Briscoe, J. J. Bourn Hall, Bourn, Cambridge.
1905. §Briscoe, Miss. Bourn Hall, Bourn, near Cambridge.
1898. ‡Bristol, The Right Rev. G. F. Browne, D.D., Lord Bishop of. 17 The Avenue, Clifton, Bristol.
1879. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1906. §Broad, John M. The Elms, 2 Nicoll-road, Harlesden, N.W.
1905. *Broadwood, Brigadier-General R. G. The Deodars, Bloemfontein, South Africa.
1905. §Brock, Dr. B. G. P.O. Box 216, Germiston, Transvaal.
1907. §Brockington, W. A., M.A. Leicestershire County Council, 38 Bowling Green-street, Leicester.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1883. *Brodie, David, M.D. Slingsby Villa, Regent's Park-road, N.
1901. ‡Brodie, T. G., M.D., F.R.S. 4 Lancaster-terrace, Regent's Park, N.W.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1905. ‡Brodigan, C. B. Brakpan Mines, Johannesburg.
1903. ‡Brodrick, Harold, M.A. (Local Sec., 1903.) 7 Aughton-road, Birkdale, Southport.
1904. ‡Bromwich, T. J. I'A., M.A., F.R.S., Professor of Mathematics in Queen's College, Galway.
1906. ‡Brook, Stanley. 18 St. George's-place, York.
1905. *Brooke, Geoffrey. Christ Church Vicarage, Mirfield, S.O., Yorkshire.
1906. §Brooks, F. T. Caius College, Cambridge.
1883. *Brotherton, E. A., M.P. Arthington Hall, Wharfedale, viâ Leeds.
1901. §Brough, Bennett H., F.I.C., F.G.S. 28 Victoria-street, S.W.
1883. *Brough, Mrs. Charles S. 4 Eastern Villas-road, Southsea.
1886. ‡Brough, Joseph, LLD., Professor of Logic and Philosophy in University College, Aberystwyth.

Year of Election.

1905. ‡Brown, A. R. Trinity College, Cambridge.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871), Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1905. §Brown, Professor Ernest William, M.A., D.Sc., F.R.S. Yale University, New Haven, Conn., U.S.A.
1903. ‡Brown, F. W. 6 Rawlinson-road. Southport.
1870. §Brown, Horace T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904– .) 52 Nevern-square, S.W.
1870. *Brown, J. Campbell, D.Sc., F.C.S., Professor of Chemistry in the University of Liverpool.
1905. ‡Brown, J. Ellis. Durban, Natal.
1876. §Brown, John, F.R.S. (Local Sec. 1902.) Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. 2 Glebe-terrace, Rondebosch, Cape Colony.
1895. *Brown, John Charles, 39 Burlington-road, Sherwood, Nottingham.
1905. ‡Brown, John S. Longhurst, Dunmurry, Belfast.
1905. ‡Brown, L. Clifford. Beyer's Kloof, Klapmuts, Cape Colony.
1882. *Brown, Mrs. Mary. 2 Glebe-terrace, Rondebosch, Cape Colony.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1886. ‡Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1905. ‡Brown, R. C. Strathyre, Troyville, Transvaal.
1901. ‡Brown, R. N. R., B.Sc. University College, Dundee.
1906. §Browne, Charles E., B.Sc. Christ's Hospital, West Horsham.
1900. *Browne, Frank Balfour, M.A., F.R.S.E., F.Z.S. Larne Harbour, near Belfast.
1895. *Browne, H. T. Doughty. 10 Hyde Park-terrace, W.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1905. *Browne, James Stark, F.R.A.S. The Red House, Mount-avenue, Ealing, W.
1891. ‡Browne, Montagu, F.G.S. Corporation Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's-hill, Carlow, Ireland.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1905. §Bruce, Colonel David, C.B., M.B., F.R.S. (Pres. I, 1905.) War Office, 68 Victoria-street, S.W.
1905. ‡Bruce, Mrs. 3p Artillery-mansions, Victoria-street, S.W.
1893. ‡Bruce, William S. 11 Mount Pleasant, Joppa, Edinburgh.
1902. ‡Bruce-Kingsmill, Major J., R.A. Royal Arsenal, Woolwich.
1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1896. *Brunner, Right Hon. Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡Brunton, Sir T. Lauder, M.D., D.Sc., F.R.S. 10 Stratford-place, Cavendish-square, W.
1905. ‡Brunton, Lady. 10 Stratford-place, Cavendish-square, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1886. *Bryan, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. *Bryce, Rev. Professor George, D.D., LL.D. Kilmadock, Winnipeg, Canada.
1901. ‡Bryce, Thomas H. 2 Granby-terrace, Hillhead, Glasgow.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.

Year of
Election.

1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1902. *Buchanan, Miss Florence, D.Sc. University Museum, Oxford.
1905. §Buchanan, Right Hon. Sir John. Clareinch, Claremont, Cape Town.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. Christ's College, Cambridge.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1904. §Buckwell, J. C. North Gate House, Pavilion, Brighton.
1893. §BULLEID, ARTHUR, F.S.A. The Old Vicarage, Midsomer Norton, Bath.
1903. *Bullen, Rev. R. Ashington, F.L.S., F.G.S. Englemoor, Heathside-road, Woking, Surrey.
1905. ‡Burbury, Mrs. A. A. 17 Upper Phillimore-gardens, W.
1905. ‡Burbury, Miss A. D. 17 Upper Phillimore-gardens, W.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1907. §Burch, George J., M.A., D.Sc. F.R.S. Norham Hall, Oxford.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1905. ‡Burdon, E. R., M.A. Ikenhilde, Royston, Herts.
1894. ‡BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Colonel Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1905. ‡Burmeister, H. A. P. 78 Hout-street, Cape Town.
1904. ‡Burn, R. H. 21 Stanley-crescent, Notting-hill, W.
1883. *Burne, Major-General Sir Owen Tudor, G.C.I.E., K.C.S.I., F.R.G.S. 132 Sutherland-gardens, Maida Vale, W.
1885. *Burnett, W. Kendall, M.A. Migvie House, North Silver-street, Aberdeen.
1905. ‡Burroughes, James S., F.R.G.S. The Homestead, Seaford, Sussex.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. 11 Union-crescent, Margate.
1904. ‡Burtt, Arthur H., D.Sc. 4 South View, Holgate, York.
1906. §Burtt, Philip. Swarthmore, St. George's-place, York.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. ‡Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1906. §Bushell, H. A. Molton House, Holgate Hill, York.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. *Butterworth, W. Verona, 10 Derbe-road, St. Anne's-on-the-Sea, Lancashire.
1905. ‡Buxton, Miss F. M. 42 Grosvenor-gardens, S.W.
1905. §Buxton, F. W. 42 Grosvenor-gardens, S.W.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1899. ‡Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.

1861. *Caird, James Key, LL.D. 8 Roseangle, Dundee.
1905. ‡Calderwood, J. M. P.O. Box 2295, Johannesburg.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1907. §Caldwell, K. S. St. Bartholomew's Hospital, S.E.
1897. §CALLENDAR, HUGH L., M.A., LL.D., F.R.S. (Council, 1900–06), Professor of Physics in the Royal College of Science, S.W.

Year of
Election.

1857. ‡CAMERON, Sir CHARLES A., C.B., M.D. 15 Pembroke-road, Dublin.
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1901. ‡Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1890. ‡CANNAN, EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 46 Wellington-square, Oxford.
1905. ‡Cannan, Gilbert. King's College, Cambridge.
1897. §Cannon, Herbert. Woodbank, Erith, Kent.
1904. ‡Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1905. *Caporn, Dr. A. W. Roeland-street Baths, Cape Town.
1894. ‡CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1896. *Carden, H. Vandeleur. Fassaroe, Walmer.
1902. ‡Carpenter, G. H., B.Sc., Professor of Zoology in the Royal College of Science, Dublin.
1906. *Carpenter, H. C. H. 11 Oak-road, Withington, Manchester.
1905. §Carpmael, Edward, F.R.A.S., M.Inst.C.E. 24 Southampton-buildings, Chancery-lane, W.C.
1893. ‡CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1906. *Carr, Richard E., British Vice-Consul, Cordoba, Spain.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1905. ‡Carrick, Dr. P.O. Box 646, Johannesburg.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 14 Vermont-road, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM (Local Sec. 1886). 30 Westfield-road, Birmingham.
1899. ‡Carslaw, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1903. *Cart, Rev. Henry. 49 Albert-court, Kensington Gore, S.W.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
1900. *Carter, Rev. W. Lower, M.A., F.G.S. Belfield, Oxton, Birkenhead.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. 21 Parsons-lane, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Rosehill-street, Derby.
1894. ‡Carus, Dr. Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, S.W.
1901. ‡Carver, Thomas A. B., D.Sc., Assoc.M.Inst.C.E. 118 Napiershall-street, Glasgow.
1899. **Case, J. Monckton. Town Office, Uitenhage, Cape Colony.*
1897. *Case, Willard E. Auburn, New York, U.S.A.
1873 *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1904 ‡Caspair, W. A. National Physical Laboratory, Bushy House, Teddington, Middlesex.
1900. *Cassie, W., M.A., Professor of Physics in the Royal Holloway College. Brantwood, Englefield Green.
1886. *Cave-Moyle, Mrs. Isabella. St. Paul's Vicarage, Cheltenham.
Cayley, Digby. Brompton, near Scarborough.
1905. *Challenor, Bromley. The Firs, Abingdon.
1905. *Challenor, Miss E. M. The Firs, Abingdon.

Year of Election.

1905. ‡Chamberlain, Miss H. H. Ingleneuk, Upper St. John's-road, Sea Point, Cape Colony.
1901. §Chamen, W. A. South Wales Electrical Power Distribution Company, Royal-chambers, Queen-street, Cardiff.
1905. ‡Champion, G. A. Haraldene, Chelmsford-road, Durban, Natal.
1881. *Champney, John E. 27 Hans-place, S.W.
1908. §Chance, Sir Arthur, M.D. 90 Merrion-square, Dublin.
1907. *Chapman, Alfred Chaston, F.I.C. 8 Duke-street, Aldgate, E.C.
1902. §Chapman, D. L. 10 Parsonage-road, Withington, Manchester.
1899. §Chapman, Professor Sydney John, M.A. Burnage Lodge, Levenshulme, Manchester.
1905. ‡Chassigneux, E. 12 Tavistock-road, Westbourne-park, W.
1903. ‡Chaster, G. W. 42 Talbot-street, Southport.
1904. *Chattaway, F. D., M.A., D.Sc., Ph.D., F.R.S. Longfield, Kenton-road, Harrow.
1884. *CHATTERTON, GEORGE, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *CHATTOCK, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1867. *Chatwood, Samuel, F.R.A.S. Hawksmoor, Windermere.
1904. *Chaundy, Theodore William. 49 Broad-street, Oxford.
1900. §Cheesman, W. Norwood, J.P., F.L.S. The Crescent, Selby.
1874. *Chermside, Major-General Sir H. C., R.E., G.C.M.G., C.B. Newstead Abbey, Nottingham.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1894. ‡CHISHOLM, G. G., M.A., B.Sc., F.R.G.S. (Pres. E, 1907.) 59 Drakefield-road, Upper Tooting, S.W.
1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. ‡Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1899. §Chitty, G. W. Brockhill Park, Hythe, Kent.
1904. ‡Chivers, John, J.P. Histon, Cambridgeshire.
1882. ‡Chorley, George. Midhurst, Sussex.
1893, *CHREE, CHARLES, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1900. *Christie, R. J. Duke-street, Toronto, Canada.
1875. *Christopher, George. F.C.S. May Villa, Lucien-road, Tooting-common, S.W.
1876. *CHRYSTAL, GEORGE, M.A., LL.D., F.R.S.E. (Pres. A, 1885.) Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1905. ‡Chudleigh, C. P.O. Box 743, Johannesburg.
1870. §CHURCH, A. H., M.A., F.R.S., F.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §CHURCH, Colonel G. EARL, F.R.G.S. (Pres. E, 1898.) 216 Cromwell-road, S.W.
1903. §Clapham, J. H., M.A., Professor of Economics in the University of Leeds.
1901. §Clark, Archibald B., M.A. 16 Comely Bank-street, Edinburgh.
1905. *Clark, Cumberland, F.R.G.S. 29 Chepstow-villas, Bayswater, W.
1907. *Clark, Mrs. Cumberland. 29 Chepstow-villas, Bayswater, W.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. South African Museum, Cape Town.
1881. *Clark, J. Edmund, B.A., B.Sc. Asgarth, Riddlesdown-road, Purley, Surrey.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.

Year of
Election.

1887. ‡Clarke, C. Goddard, J.P. South Lodge, Champion Hill, S.E.
1907. *Clarke, E. Russell. 11 King's Bench-walk, Temple, E.C.
1875. ‡CLARKE, JOHN HENRY. (Local Sec. 1875.) 4 Worcester-terrace, Clifton, Bristol.
1902. §Clarke, Miss Lilian J., B.Sc., F.L.S. 43 Glasslyn-road, Crouch End, N.
1905. ‡Clarke, Rev. W. E. C., M.A. P.O. Box 1144, Pretoria.
1889. *CLAYDEN, A. W., M.A., F.G.S. 5 The Crescent, Mount Radford, Exeter.
1890. **Clayton, William Wikely. Gipton Lodge, Leeds.*
1861. ‡CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1905. §Cleland, Mrs. 2 The University, Glasgow.
1905. §Cleland, J. R. 2 The University, Glasgow.
1902. ‡Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §Clerk, Dugald, M.Inst.C.E. 18 Southampton-buildings, W.C.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1906. §Close, Major C. F., R.E., C.M.G., F.R.G.S. Army and Navy Club, Pall Mall, S.W.
1883. *CLOWES, FRANK, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E.
1891. *Coates, Henry. Pitcullen House, Perth.
1903. *Coates, W. M. Queens' College, Cambridge.
1884. §Cobb, John. Fitzherries, Abingdon.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1908. §Cochrane, Robert, I.S.O., LL.D., F.S.A. 17 Highfield-road, Dublin.
1901. ‡Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone-road, Upper Norwood, S.E.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1908. §Coffey Denis J., M.B. 2 Arkendale-road, Glenageary, Co. Dublin.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. Passaic, Kew.
1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.
1884. *Cohen, Sir Benjamin L., Bart. 30 Hyde Park-gardens, W.
1901. §Cohen, N. L. 11 Hyde Park-terrace, W.
1901. *Cohen, R. Waley, B.A. 11 Sussex-square, W.
1906. *Coker, Professor Ernest George, M.A., D.Sc., F.R.S.E. City and Guilds of London Technical College, Finsbury, E.C.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby, William Henry. Carregwen, Aberystwyth.
1893. §Cole, Grenville A. J., F.G.S., Professor of Geology in the Royal College of Science, Dublin.
1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1897. §COLEMAN, Dr. A. P. 476 Huron-street, Toronto, Canada.
1899. §Coleman, William, F.R.A.S. The Shrubbery, Buckland, Dover.
1899. ‡Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1893. ‡Collinge, Walter E. The University, Birmingham.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.

Year of Election.

1876. ‡COLLINS, J. H., F.G.S. Crinnis House, Par Station, Cornwall.
1865. *Collins, James Tertius. Church-road, Edgbaston, Birmingham.
1905. ‡Collins, Rev. Spencer. The Rectory, Victoria West, Cape Colony.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1907. §COLSON, ALFRED, M.Inst.C.E. (Local Sec. 1907.) Millstone-lane, Leicester.
1905. *Combs, Rev. Cyril W., M.A. Elverton, Castle-road, Newport, Isle of Wight.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1902. ‡Conway, A. W. 100 Leinster-road, Rathmines, Dublin.
1903. ‡Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1888. ‡Cooley, George Parkin. Constitutional Club, Nottingham.
1899. *Coomaraswamy, A. K., D.Sc., F.L.S., F.G.S. Broad Campden, Gloucestershire.
1902. *Coomaraswamy, Mrs. A. K. Broad Campden, Gloucestershire.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1907. §Cooper, William. Education Offices, Becket-street, Derby.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1904. *COPEMAN, S. MONCKTON, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1904. *Copland, Miss Louisa. 14 Brunswick-gardens, Kensington, W.
1905. ‡Corben, J. H. Education Department, Klerksdorp, Transvaal.
1901. ‡Corbett, A. Cameron, M.P. Thornliebank House, Glasgow.
1887. *Corcoran, Bryan. Fairlight, 22 Oliver-grove, South Norwood, S.E.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1883. *Core, Professor Thomas H., M.A. Groombridge House, Withington, Manchester.
1901. *Cormack, Professor J. D., B.Sc. University College, Gower-street, W.C.
1893. *Corner, Samuel, B.A., B.Sc. Abbotsford House, Waverley-street, Nottingham.
1889. ‡CORNISH, VAUGHAN, D.Sc., F.R.G.S. 31 Kensington Gardens-square, W.
1905. ‡Cornish-Bowden, A. H. Surveyor-General's Office, Cape Town.
1884. *Cornwallis, F. S. W., M.P., F.L.S. Linton Park, Maidstone.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1900. §Cortie, Rev. A. L., S.J., F.R.A.S. Stonyhurst College, Blackburn.
1905. ‡Cory, Professor G. E., M.A. Rhodes University College, Grahams Town, Cape Colony.
1906. ‡Cotsworth, Moses B. Acomb, York.
1906. §Cotter, J. R. 21 Mayfield-road, Terenure Park, Dublin.
1874. *COTTERILL, J. H., M.A., F.R.S. Braeside, Speldhurst, Kent.
1905. ‡Cottrill, G. St. John, P.O. Box 4829, Johannesburg.
1904. ‡Coulter, G. G. 28 Pall Mall, S.W.
1896. ‡COURTNEY, Right Hon. Lord (Pres. F, 1896). 15 Cheyne-walk, Chelsea, S.W.
1905. ‡Cousens, R. L. P.O. Box 4261, Johannesburg.
1872. *Cowan, Thomas William, F.L.S., F.G.S. Upcott House, Taunton, Somersetshire.
1903. ‡Coward, H. Knowle Board School, Bristol.
1900. §Cowburn, Henry. Dingle Head, Leigh, Lancashire.
1905. ‡Cowell, John Ray. P.O. Box 2141, Johannesburg.
1895. *COWELL, PHILIP H., M.A., F.R.S. Royal Observatory, Greenwich, and 74 Vanbrugh-park, Blackheath, S.E.

Year of Election.

1899. ‡Cowper-Coles, Sherard, Assoc.M.Inst.C.E. 82 Victoria-street, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1906. §Cox, S. Herbert, Professor of Mining in the Royal College of Science, S.W.
1905. ‡Cox, W. H. Royal Observatory, Cape Town.
1902. ‡*Craig, H. C. Strandtown, Belfast.*
1884. §CRAIGIE, Major P. G., C.B., F.S.S. (Pres. F, 1900.) West Wellow, Romsey, Hampshire.
1906. ‡Craik, Sir Henry, K.C.B., LL.D., M.P. 5A Dean's-yard, Westminster, S.W.
1906. §Cramp, William. Redthorn, Whalley-road, Manchester.
1905. *Cranswick, Wm. Franceys. 34 Boshof-road, Kimberley.
1906. ‡CRAVEN, HENRY. (Local Sec. 1906.) Clifton Green, York.
1887. *Craven, Thomas, J.P. Woodheyes-park, Ashton-upon-Mersey.
1905. ‡Crawford, Mrs. A. M. Marchmont, Rosebank, near Cape Town.
1905. ‡Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E. South African College, Cape Town.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colington-road, Edinburgh.
1905. ‡Crawford, W. C., jun. 1 Lockharton-gardens, Colington-road, Edinburgh.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. 2 Cavendish-square, W.; and Haigh Hall, Wigan.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1870. *Crawshay, Mrs. Robert. Caversham-park, Reading.
1885. §CREAK, Captain E. W., C.B., R.N., F.R.S. (Pres. E., 1903; Council, 1896–1903.) 9 Hervey-road, Blackheath, S.E.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1904. ‡Crilly, David. 7 Well-street, Paisley.
1880. *Crisp, Sir Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1905. §Croft, Miss Mary. 17 Pelham-crescent, S.W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. *Croke, John O'Byrne, M.A. Clouncagh, Ballingarry-Lacy, Co. Limerick.
1885. ‡CROMBIE, J. W., M.A., M.P. (Local Sec. 1885.) Balgownie Lodge, Aberdeen.
1903. *Crompton, Holland. Binfield, Northwood, Middlesex.
1901. ‡CROMPTON, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington-court, W.
1887. ‡CROOK, HENRY T., M.Inst.C.E. 9 Albert-square, Manchester.
1898. §Crooke, William. Langton House, Charlton Kings, Cheltenham.
1865. §CROOKES, Sir WILLIAM, D.Sc., F.R.S., V.P.C.S. (PRESIDENT, 1898; Pres. B, 1886; Council 1885–91.) 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *CROOKSHANK, E. M., M B. Ashdown Forest, Forest Row, Sussex.
1905. ‡Crosfield, Hugh T. Walden, Coombe-road, Croydon.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. 3 Fulwood-park, Liverpool.
1904. §Cross, Professor Charles R. Massachusetts Institute of Technology, Boston, U.S.A.

Year of Election.

1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1905. §Cross, Robert. 13 Moray-place, Edinburgh.
1904. *Crossley, A. W., D.Sc., Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 10 Crediton-road, West Hampstead, N.W.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham-lane, Bradford.
1883. *Culverwell, Edward P., M.A., Professor of Education in Trinity College, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1898. ‡Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1905. §Cunningham, Miss A. 2 St. Paul's-road, Cambridge.
1882. *Cunningham, Lieut.-Colonel Allan, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1905. ‡Cunningham, Andrew. Earlsferry, Campground-road, Mowbray, South Africa.
1877. *Cunningham, D. J., M.D., D.C.L., F.R.S., F.R.S.E. (Pres. H, 1901; Council, 1902–), Professor of Anatomy in the University of Edinburgh.
1885. ‡Cunningham, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡Cunningham, Robert O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Rev. W., D.D., D.Sc. (Pres. F, 1891, 1905.) Trinity College, Cambridge.
1892. ‡Cunningham-Craig, E. H., B.A., F.G.S. 14a Dublin-street, Edinburgh.
1900. *Cunnington, William A., B.A., Ph.D., F.Z.S. 13 The Chase, Clapham Common, S.W.
1892. *Currie, James, M.A., F.R.S.E. Larkfield, Wardie-road, Edinburgh.
1905. §Currie, Dr. O. J. 24 Longmarket-street, Pietermaritzburg, Natal.
1905. ‡Currie, W. P. P.O.Box 2010, Johannesburg.
1902. ‡Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.
1883. ‡Cushing, Mrs. M. Allee-strasse 16i, Hanover, Germany.
1881. §Cushing, Thomas, F.R.A.S. Allee-strasse 16i, Hanover, Germany.
1907. §Cushny, Arthur R., M.D., F.R.S., Professor of Pharmacology in University College, Gower-street, W.C.
1905. ‡Cuthbert, W. M. The Red House, Kenilworth, Cape Colony.
1905. ‡Cuthbert, Mrs. W. M. The Red House, Kenilworth, Cape Colony.

1898. §Dalby, W. E., D.Sc., M.Inst.C.E., Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W.
1889. *Dale, Miss Elizabeth. Garth Cottage, Oxford-road, Cambridge.
1906. §Dale, William, F.S.A., F.G.S. The Lawn, Archer's-road, Southampton.
1907. §Dalgliesh, Richard, J.P., D.L. Ashfordby Place, near Melton Mowbray.
1870. ‡Dallinger, Rev. W. H., D.D., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.

Year of Election.

1904. *Dalton, J. H. C., M.D. The Plot, Adams-road, Cambridge.
1862. ‡Danby, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1905. §Daniel, Miss A. M. 3 St. John's-terrace, Weston-super-Mare.
1901. ‡Daniell, G. F., B.Sc. Woodberry, Oakleigh Park, N.
1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1897. §Darbishire, F. V., B.A., Ph.D. South-Eastern Agricultura College, Wye, Kent.
1903. §Darbishire, Dr. Otto V. The University, Manchester.
1861. *Darbishire, Robert Dukinfield, B.A. (Local Sec. 1861.) Victoria Park, Manchester.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. ‡Darwin, Francis, M.A., M.B., F.R.S., F.L.S. (President-Elect; Pres. D, 1891; Pres. K, 1904; Council, 1882–84, 1897–1901.) 13 Madingley-road, Cambridge.
1881. *Darwin, Sir George Howard, K.C.B., M.A., LL.D., F.R.S., F.R.A.S. (President, 1905; Pres. A, 1886; Council, 1886–1892), Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1905. ‡Darwin, Lady. Newnham Grange, Cambridge.
1878. *Darwin, Horace, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *Darwin, Major Leonard, Hon. Sec. R.G.S. (Pres. E, 1896; Council, 1899–1905.) 12 Egerton-place, South Kensington, S.W.
1880. *Davey, Henry, M.Inst.C.E. Parliament-chambers, Great Smith-street, Westminster, S.W.
1898. ‡Davey, William John. 6 Water-street, Liverpool.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1904. §Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N., F.G.S. St. Chad's, Weston-super-Mare.
1906. ‡Davies, S. H. White Cross Lodge, York.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., Professor of Semitic Languages in University College, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1873. *Davis, Alfred. 37 Ladbroke-grove, W.
1905. ‡Davis, C. R. S. National Bank-buildings, Johannesburg.
1896. *Davis, John Henry Grant. Hillsborough, Wednesbury, Staffordshire.
1905. §Davis, Luther. The Oaks, Malvern.
1885. *Davis, Rev. Rudolf. 23 Northfield, Bridgwater.
1905. ‡Davy, Mrs. Alice Burtt. P.O. Box 434, Pretoria.
1905. ‡Davy, Joseph Burtt, F.R.G.S., F.L.S. P.O. Box 434, Pretoria.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. ‡Dawkins, W. Boyd, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88), Professor of Geology and Palæontology in the University of Manchester. Fallowfield House, Fallowfield, Manchester.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington Hall, Burnsall, Skipton-in-Craven.
1901. *Dawson, P. The Acre, Maryhill, Glasgow.

Year of Election.

1905. ‡Dawson, Mrs. The Acre, Maryhill, Glasgow.
1884. ‡DAWSON, SAMUEL. (Local Sec. 1884.) 258 University-street, Montreal, Canada.
1906. §Dawson, William C. Hessle, R.S.O., East Yorkshire.
1870. *DEACON, G. F., LL.D., M.Inst.C.E. (Pres. G, 1897.) 19 Warwick-square, S.W.
1900. ‡Deacon, M. Whittington House, near Chesterfield.
1901. *Deasy, Capt. H. H. P. Cavalry Club, Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. (Pres. B, 1869 ; Council, 1870–75.) 4 Schlangenweg, Cassel, Hessen.
1893. *Deeley, R. M. 38 Charnwood-street, Derby.
1878. ‡DELANY, Very Rev. WILLIAM, LL.D. (VICE-PRESIDENT, 1908.) University College, Dublin.
1907. §De Lisle, Mrs. Edwin. Charnwood Lodge, Coalville, Leicestershire.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1902. ‡Dendy, Arthur, D.Sc., F.L.S., Professor of Zoology in King's College, London, W.C.
1908. §Dennehy, W. F. 23 Leeson-park, Dublin.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in the University of Sheffield.
1905. ‡Denny, G. A. 603–4 Consolidated-buildings, Fox-street, Johannesburg.
1896. *DERBY, The Right Hon. the Earl of, K.G., G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, W.
1907. *Desch, Cecil H., D.Sc., Ph.D. 93 Mount Pleasant-road, South Tottenham, N.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1903. ‡*Devereux, Rev. F. R. Price. Drachenfeld, Tenison-avenue, Cambridge.*
1899. ‡DEVONSHIRE, The Duke of, K.G., D.C.L., F.R.S. Devonshire House, Piccadilly, W.
1868. *DEWAR, Sir JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (PRESIDENT, 1902 ; Pres. B, 1879 ; Council, 1883–88.) 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Lady. 1 Scroope-terrace, Cambridge.
1905. ‡Dewar, W. R. Agricultural Department, Bloemfontein, South Africa.
1884. *Dewar, William, M.A. Horton House, Rugby.
1905. ‡Dewhirst, Miss May. Pembroke House, Oxford-road, Colchester.
1901. ‡Dick, George Handasyde. 31 Hamilton-drive, Hillhead, Glasgow.
1906. §Dickinson, Miss F. A. Burton House, Clifton, York.
1904. ‡Dickson, Charles Scott, K.C., LL.D. Carlton Club, Pall Mall, S.W.
1881. ‡Dickson, Edmund, M.A., F.G.S. Claughton House, Garstang, R.S.O., Lancashire.
1887. §DICKSON, H. N., D.Sc., F.R.S.E., F.R.G.S. The Lawn, Upper Redlands-road, Reading.
1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin

Year of Election.

1901. §Dines, W. H., F.R.S. Oxshott, Leatherhead.
1900. §DIVERS, Dr. EDWARD, F.R.S. (Pres. B, 1902.) 3 Canning-place, Palace Gate, W.
1898. *Dix, John William S. Hampton Lodge, Durdham Down, Clifton, Bristol.
1905. §Dixey, F. A., M.A., M.D. Wadham College, Oxford.
1899. *DIXON, A. C., D.Sc., F.R.S. Professor of Mathematics in Queen's College, Belfast. Almora, Myrtlefield-park, Belfast.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork.
1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.
1905. ‡Dixon, Miss E. K. 16 Mount Pleasant, Darlington.
1888. §Dixon, Edward T. Racketts, Hythe, Hampshire.
1900. *Dixon, Major George, M.A. St. Bees, Cumberland.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S. (Pres. B, 1894), Professor of Chemistry in the Victoria University, Manchester.
1902. ‡Dixon, Henry H., D.Sc., Professor of Botany in the University of Dublin. Clevedon, Temple-road, Dublin.
1907. *Dixon, Professor Walter E. The Museums, Cambridge.
1902. ‡Dixon, W. V. Scotch Quarter, Carrickfergus.
1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.
1890. ‡Dobbie, James J., D.Sc., F.R.S., Director of the Museum of Science and Art, Edinburgh.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Fylde Cottage, Branksome-avenue, Bournemouth.
1902. ‡Dobbs, F. W. 2 Willowbrook, Eton, Windsor.
1905. ‡Dobson, Professor J. H. Transvaal Technical Institute, Johannesburg.
1908. §DODD, Hon. Mr. Justice (Local Treasurer, 1908). 26 Fitzwilliam-square, Dublin.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1905. ‡Dodds, Dr. W. J. Valkenberg, Mowbray, Cape Colony.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1904. §Doncaster, Leonard. The University, Birmingham.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. §Donnan, F. G., M.A., Ph.D., Professor of Physical Chemistry. The University, Liverpool.
1905. ‡Donnan, H. Allandale, Claremont, Cape Colony.
1908. §Donnelly, Most Rev. Dr. Nicholas, Bishop of Canea. St. Mary's, Haddington-road, Dublin.
1905. ‡Donner, Arthur. Helsingfors, Finland.
1905. §Donovan, Surgeon-General William, C.B. Army Headquarters,
1905. §Dornan, Rev. S. S. Training Institution, Morija, Basutoland, South Africa.
1863. *Doughty, Charles Montagu. 26 Grange-road, Eastbourne.
1905. ‡Douglas-McMillan, Mrs. A. 31 Ford-street, Jeppestown, Transvaal.
1884. ‡Dove, Miss Frances. Wycombe Abbey School, Buckinghamshire.
1903. ‡Dow, Miss Agnes R. 81 Park-mansions, Knightsbridge, S.W.
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. Merry Hall, Ashtead, Surrey.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1905. ‡Drew, H. W., M.B., M.R.C.S. Mocollup Castle, Ballyduff, S.O., Co. Waterford.

Year of Election.

1906. *Drew, Joseph Webster, M.A., LL.M. Fashoda, Scarborough.
1906. *Drew, Mrs. Fashoda, Scarborough.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. (Local Sec., 1894.) Yardley Lodge, 9 Crick-road, Oxford.
1905. ‡Drury, H. P.O. Box 2305, Johannesburg.
1905. ‡Drury, Mrs. H. P.O. Box 2305, Johannesburg.
1907. §Drysdale, Charles V. Northampton Institute, Clerkenwell, E.C.
1892. ‡Du Bois, Professor Dr. H. Herwarthstrasse 4, Berlin, N.W.
1905. ‡Dubois, Raymond, B.Sc. Groot Constantia, Wynberg, Cape Colony.
1905. ‡Dubois, Mrs. Raymond. Groot Constantia, Wynberg, Cape Colony.
1856. *DUCIE, The Right Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.D., Sc.D. Jesus College, Cambridge.
1895. *Duddell, William, F.R.S. 47 Hans-place, S.W.
1906. ‡Dudgeon, Gerald C., Superintendent of Agriculture for British West Africa. Bathurst, Gambia, British West Africa.
1904. *Duffield, W. G. Physical Laboratory, The University, Manchester.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1896. *DUNKERLEY, STANLEY, D.Sc., M.Inst.C.E., Professor of Engineering in the Victoria University, Manchester.
1876. ‡Dunnachie, James. 48 West Regent-street, Glasgow.
1884. §Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1893. *Dunstan, M. J. R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *DUNSTAN, Professor WYNDHAM, M.A., LL.D., F.R.S., V.P.C.S. (Pres. B, 1906; Council, 1905–), Director of the Imperial Institute, S.W.
1905. §Dutton, C. L. O'Brien. High Commissioner's Office, Johannesburg.
1895. *DWERRYHOUSE, ARTHUR R., D.Sc., F.G.S. Glyn Garth, Weetwood-lane, Headingley, Leeds.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. Savile Club, Piccadilly, W.
1905. ‡DYSON, F. W., M.A., F.R.S. (Council, 1905–), Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh.

1905. ‡Earp, E. J. P.O. Box 538, Cape Town.
1899. ‡East, W. H. Municipal School of Art, Science, and Technology, Dover.
1871. *EASTON, EDWARD (Pres. G, 1878; Council, 1879–81). 22 Vincent-square, Westminster, S.W.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1906. §Ebbs, Mrs. A. B. Tuborg, Durham-avenue, Bromley, Kent.
1905. ‡Ebden, Hon. Alfred. Belmont, Rondebosch, Cape Colony.
1903. ‡Eccles, W. H., D.Sc. 16 Worfield-street, Battersea, S.W.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. Sywell House, Llandudno.

Year of Election.

1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council, 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1908. §Edmondson, Thomas. Creevagh, Orwell Park, Dublin.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 4 Chichester-terrace, Kemp Town, Brighton.
1901. *EDRIDGE-GREEN, F. W., M.D., F.R.C.S. Hendon Grove, Hendon, N.W.
1905. ‡Edwards, Bidewell. 80 St. George's-street, Cape Town.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 290 Trinity-road, Wandsworth, S.W.
1903. ‡Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1901. ‡Eggar, W. D. Willowbrook, Eton, Windsor.
1907. *Elderton, W. Palin. Allington, Telford-avenue, S.W.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 18 Cornwall-terrace, Regent's Park, N.W.
1904. §Eliot, Sir John, K.C.I.E., M.A., F.R.S. 79 Alleyn-park, Dulwich, S.E.
1901. *Elles, Miss Gertrude L. Newnham College, Cambridge.
1904. ‡Elliot, Miss Agnes I. M. Newnham College, Cambridge.
1904. ‡Elliot, R. H. Clifton Park, Kelso, N.B.
1904. ‡Elliot, T. R. B. Holme Park, Rotherfield, Sussex.
1891. ‡Elliott, A. C., D.Sc., M.Inst.C.E., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1905. §Elliott, C. C., M.D. 5 Bureau-street, Cape Town.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1906. *Ellis, David, D.Sc., Ph.D. Technical College, Glasgow.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1906. §ELLIS, HERBERT. 120 Regent-road, Leicester.
1880. *ELLIS, JOHN HENRY (Local Sec. 1883). 3 Carlisle-terrace, The Hoe, Plymouth.
1891. §Ellis, Miss M. A. 129 Walton-street, Oxford.
1906. ‡ELMHIRST, CHARLES E. (Local Sec. 1906.) 29 Mount-vale, York.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1869. *Enys, John Davies. Enys, Penryn, Cornwall.
1894. ‡*Erskine-Murray, James, D.Sc., F.R.S.E. University College, Nottingham.*
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1887. *Estcourt, Charles, F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1887 *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.

Year of Election.

1889. *EVANS, A. H., M.A. 9 Harvey-road, Cambridge.
1905. ‡Evans, Mrs. A. H. 9 Harvey-road, Cambridge.
1870. *EVANS, ARTHUR JOHN, M.A., LL.D., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1883. *Evans, Mrs. James C. Casewell Lodge, Llanwrtyd Wells, South Wales.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., F.R.S., F.S.A., F.L.S., F.G.S. (PRESIDENT, 1897; Pres. C, 1878; Pres. H, 1890; Council, 1868–74, 1875–82, 1889–96.) Britwell, Berkhamsted, Herts.
1897. *Evans, Lady. Britwell, Berkhamsted, Herts.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1905. ‡Evans, R. O. Ll. Broom Hall, Chwilog, R.S.O., Carnarvonshire.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Abbot's Barton, Canterbury.
1905. ‡Evans, T. H. 9 Harvey-road, Cambridge.
1905. ‡Evans, Thomas H. P.O. Box 1276, Johannesburg.
1865. *Evans, William. The Spring, Kenilworth.
1903. ‡Evatt, E. J., M.B. 8 Kyveilog-street, Cardiff.
1871. ‡Eve, H. Weston, M.A. 37 Gordon-square, W.C.
1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
1872. ‡EVERSLEY, Right Hon. Lord, F.R.S. (Pres. F, 1879; Council, 1878–80.) 18 Bryanston-square, W.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1874. ‡EWART, Sir W. QUARTUS, Bart. (Local Sec. 1874.) Glenmachan, Belfast.
1876. *EWING, JAMES ALFRED, M.A., LL.D., F.R.S., F.R.S.E., M.Inst.C.E. (Pres. G, 1906), Director of Naval Education. Admiralty, S.W.
1903. §Ewing, Peter, F.L.S. The Frond, Uddingston, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1905. ‡Eyre, Dr. G. G. Claremont, Cape Colony.
Eyton, Charles. Hendred House, Abingdon.

1906. *Faber, George D., M.P. 14 Grosvenor-square, W.
1901. *Fairgrieve, M. McCallum. 115 Dalkeith-road, Edinburgh.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1908. §Falkiner, C. Litton. Mount Mapas, Killiney, Co. Dublin.
1902. §Fallaize, E. N., M.A. 25 Alexandra-mansions, Middle-lane, Hornsey, N.
1907. *Fantham, H. B. 30 Salisbury-road, West Ealing, W.
1898. ‡Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1877. ‡FARADAY, F. J., F.L.S., F.S.S. (Local Sec. 1887.) College-chambers, 17 Brazennose-street, Manchester.
1902. §Faren, William. 11 Mount Charles, Belfast.
1892. *FARMER, J. BRETLAND, M.A., F.R.S., F.L.S. (Pres. K, 1907), Professor of Botany, Royal College of Science, S.W.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1904. ‡Farnworth, Miss Olive. Broadlands, Goldthorn Hill, Wolverhampton.

Year of Election.

1885. *Farquharson, Mrs. R. F. O. Tillydrine, Kincardine O'Neil, N.B.
1905. ‡Farrar, Edward. P.O. Box 1242, Johannesburg.
1904. §Farrer, Sir William. 18 Upper Brook-street, W.
1903. §Faulkner, Joseph M. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1906. §Fawcett, Henry Hargreaves. 20 Margaret-street, Cavendish-square, W.
1900. ‡Fawcett, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D. 9 Foremount-terrace, Dowanhill, Glasgow.
1906. *Fearnsides, Edwin G., B.A., B.Sc. Addingford Hill, Horbury, Wakefield.
1901. *Fearnsides, W. G., M.A., F.G.S. Sidney Sussex College, Cambridge.
1905. §Feilden, Colonel H. W., C.B., F.G.S. Burwash, Sussex.
1900. *Fennell, William John. Deramore Drive, Belfast.
1904. ‡Fenton, H. J. H., M.A., F.R.S. 19 Brookside, Cambridge.
1906. ‡Ferguson, Allan. Cemetery Hotel, Newhall-lane, Preston.
1902. ‡Ferguson, Godfrey W. (Local Sec. 1902.) Cluan, Donegall Park, Belfast.
1871. *Ferguson, John, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1896. *Ferguson, Hon. John, C.M.G. Calton Lodge, Cinnamon-gardens, Colombo, Ceylon.
1901. ‡Ferguson, R. W. Municipal Technical School, the Gamble Institute, St. Helens, Lancashire.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1905. *Ferrar, H. T. Survey Department, Cairo.
1905. §Ferrar, J. E. Sidney Sussex College, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1897. ‡Field, George Wilton, Ph.D. Room 158, State House, Boston, Massachusetts, U.S.A.
1907. §Fields, Professor J. C. The University, Toronto, Canada.
1906. §Filon, L. N. G., D.Sc. Vega, Blenheim Park-road, Croydon.
1883. *Finch, Gerard B,. M.A. Howes Close, Cambridge.
1905. ‡Fincham, G. H. Hopewell, Invami, Cape Colony.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1905. §Findlay, Alexander, M.A., Ph.D., D.Sc., Lecturer on Physical Chemistry in the University of Birmingham.
1904. *Findlay, J. J., Ph.D., Professor of Education in the Victoria University, Manchester. Llwyn Celyn, 17 Oak-road, Withington, Manchester.
1902. ‡Finnegan, J., B.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1895. §Fish, Frederick J. Spursholt, Park-road, Ipswich.
1902. ‡Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1871. *Fison, Sir Frederick W., Bart., M.A., M.P., F.C.S. 64 Pont-street, S.W.
1883. ‡Fitch, Rev. J. J. 5 Chambres-road, Southport.
1885. *FitzGerald, Professor Maurice, B.A. (Local Sec. 1902.) 32 Eglantine-avenue, Belfast.

Year of Election.

1894. ‡Fitzmaurice, M., C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *FITZPATRICK, Rev. THOMAS C., President of Queens' College, Cambridge.
1904. ‡Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1904. §Fleming, Sir James. 21 Norse-road, Scotstoun, Glasgow.
1890. ‡Fletcher, B. Morley. 7 Victoria-street, S.W.
1892. ‡Fletcher, George, F.G.S. Dawson Court, Blackrock, Co. Dublin.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S.E. 28 Jermyn-street, S.W.
1906. §Fleury, H. J. University College, Aberystwyth.
1905. *Flint, Rev. W., D.D. Houses of Parliament, Cape Town.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1905. ‡Flowers, Frank. United Buildings, Foxburgh, Johannesburg.
1890. *FLUX, A. W., M.A., Professor of Political Economy in McGill University, Montreal, Canada.
1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1903. ‡Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.
1906. §Forbes, Charles Mansfeldt. 1 Oriel-crescent, Scarborough.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.
1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1905. §FORBES, Major W. LACHLAN, Sec.R.Scot.G.S. Queen-street, Edinburgh.
1890. ‡FORD, J. RAWLINSON (Local Sec. 1890). Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, H. GEORGE. Odsey, Ashwell, Baldock, Herts.
1887. ‡FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S., Perth, Western Australia.
1902. §Forster, M. O., Ph.D., D.Sc., F.R.S. Royal College of Science, S.W.
1883. ‡FORSYTH, A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897, 1905; Council, 1907-), Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1857. *FOSTER, GEORGE CAREY, B.A., LL.D., D.Sc., F.R.S. (GENERAL TREASURER, 1898–1904; Pres. A, 1877; Council, 1871–76, 1877–82.) Ladywalk, Rickmansworth.
1901. §Foster, T. Gregory, Ph.D., Principal of University College, London. Chester-road, Northwood, Middlesex.
1903. ‡Fourcade, H. G. P.O., Storms River, Humansdorp, Cape Colony.
1905. §Fowlds, Hiram. Keighley, Yorkshire.
1906. §Fowler, Oliver H., M.R.C.S. Ashcroft House, Cirencester.
1883. *Fox, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.
1883. §Fox, Sir CHARLES DOUGLAS, M.Inst.C.E. (Pres. G, 1896.) 28 Victoria-street, Westminster, S.W.
1904. *Fox, Charles J. J., B.Sc., Ph.D. 33 Ashley-road, Crouch Hill, N.
1904. §Fox, F. Douglas, M.A., M.Inst.C.E. 19 The Square, Kensington, W.
1905. §Fox, Mrs. F. Douglas. 19 The Square, Kensington, W.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *Fox, Thomas. Old Way House, Wellington, Somerset.
1881. *FOXWELL, HERBERT S., M.A., F.S.S. (Council, 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.

Year of Election.

1907. §Fraine, Miss Ethel de. Whitelands College, King's-road, Chelsea, S.W.
1905. ‡Frames, Henry J. Talana, St. Patrick's-avenue, Parktown, Johannesburg.
1905. ‡Frames, Mrs. Talana, St. Patrick's-avenue, Parktown, Johannesburg.
1905. ‡Francke, M. P.O. Box 1156, Johannesburg.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. *FRASER, ALEXANDER, M.B., Professor of Anatomy in the Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. (Local Sec. 1885.) 232 Union-street, Aberdeen.
1906. *Fraser, Miss Helen C. I., B.Sc., F.L.S. Royal Holloway College, Egham, Surrey.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1871. ‡FRASER, Sir THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1082, Drexel-building, Philadelphia, U.S.A.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. (Pres. F, 1892; Council, 1897–1903.) 4 Lower Sloane-street, S.W.
1906. §French, Fleet-Surgeon A. M. Langley, Beaufort-road, Kingston-on-Thames.
1905. ‡French, Sir Somerset R., K.C.M.G. Erritt Lodge, Kenilworth, Cape Colony.
1886. ‡FRESHFIELD, DOUGLAS W., F.R.G.S. (Pres. E, 1904.) 1 Airlie-gardens, Campden Hill, W.
1901. ‡Frew, William, Ph.D. King James-place, Perth.
1887. *Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1906. §Fritsch, Dr. F. E. 7 Prout-grove, Neasden, N.W.
1892. *Frost, Edmund, M.D. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 55 Kensington-court, W.
1898. ‡FRY, The Right Hon. Sir EDWARD, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1905. ‡Fry, H. P.O. Box 46, Johannesburg.
1875. *Fry, Joseph Storrs. 16 Upper Belgrave-road, Clifton, Bristol.
1905. *Fry, William, jun., J.P., F.R.G.S. Wilton House, Merrion-road, Dublin.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1859. ‡FULLER, FREDERICK, M.A. (Local Sec. 1859.) 9 Palace-road, Surbiton.
1869. ‡FULLER, G., M.Inst.C.E. (Local Sec. 1874.) 71 Lexham-gardens, Kensington, W.

1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1906. §Gajjar, Professor T. K., M.A. Techno-Chemical Laboratory, near Girgaum Tram Terminus, Bombay.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1875. ‡GALLOWAY, W. Cardiff.

Year of Election.

1887. *Galloway, W. J. The Cottage, Seymour-grove, Old Trafford, Manchester.

1905. ‡Galpin, Ernest E. Bank of Africa, Queenstown, Cape Colony.

1899. §Galton, Lady Douglas. Himbleton Manor, Droitwich.

1860. *GALTON, FRANCIS, M.A., D.C.L., D.Sc., F.R.S., F.R.G.S. (GEN. SEC. 1863–68; Pres. E, 1862, 1872; Pres. H, 1885; Council, 1860–63.) 42 Rutland-gate, Knightsbridge, S.W.

1888. *GAMBLE, J. SYKES, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.

1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. (Pres. D, 1882; Council, 1888–90.) 5 Avenue du Kursaal, Montreux, Switzerland.

1899. *Garcke, E. Ditton House, near Maidenhead.

1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.

1905. ‡Gardiner, J. H. 59 Wroughton-road, Balham, S.W.

1900. ‡Gardiner, J. Stanley, M.A. Gonville and Caius College, Cambridge.

1887. ‡GARDINER, WALTER, M.A., D.Sc., F.R.S. St. Awdreys, Hills-road, Cambridge.

1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.

1905. ‡Garlick, John. Thornibrae, Green Point, Cape Town.

1905. ‡Garlick, R. C. Thornibrae, Green Point, Cape Town.

1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.

1882. ‡Garnett, William, D.C.L. London County Council, Victoria Embankment, W.C.

1883. ‡GARSON, J. G., M.D. (ASSIST. GEN. SEC. 1902–04.) Moorcote, Eversley, Winchfield.

1903. ‡Garstang, A. H. 20 Roe-lane, Southport.

1903. *Garstang, T. James, M.A. Bedale's School, Petersfield, Hampshire.

1894. *GARSTANG, WALTER, M.A., D.Sc., F.Z.S., Professor of Zoology, in the University of Leeds.

1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.

1905. ‡Garthwaite, E. H. B.S.A.Co., Bulawayo, South Africa.

1889. ‡GARWOOD, Professor E. J., M.A., F.G.S. University College, Gower-street, W.C.

1870. *Gaskell, Holbrook. Erindale, Frodsham, Cheshire.

1905. ‡Gaskell, Miss C. J. The Uplands, Great Shelford, Cambridge.

1905. ‡Gaskell, Miss M. A. The Uplands, Great Shelford, Cambridge.

1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. (Pres. I, 1896; Council, 1898–1901.) The Uplands, Great Shelford, Cambridge.

1906. §Gaster, Leon. 32 Victoria-street, S.W.

1905. ‡Gaughren, Right Rev. Dr. M. Dutoitspan-road, Kimberley.

1906. ‡Gavey, H. Myddelton, M.R.C.S. 16 Broadwater Down, Tunbridge Wells.

1905. *Gearon, Miss Susan. 55 Buckleigh-road, Streatham Common, S.W.

1867. ‡GEIKIE, Sir ARCHIBALD, K.C.B., LL.D., D.Sc., Sec.R.S., F.R.S.E., F.G.S. (PRESIDENT, 1892; Pres. C, 1867, 1871, 1899; Council, 1888–1891.) 3 Sloane-court, S.W.

1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1889; Pres. E, 1892), Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.

1898. §Gemmill, James F., M.A., M.D. 21 Endsleigh-gardens, Partick-hill, Glasgow.

Year of Election.

1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1905. ‡Gentleman, Miss A. A. 9 Abercromby-place, Stirling.
1875. *George, Rev. Hereford Brooke, M.A., F.R.G.S. Holywell Lodge, Oxford.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
1899. *Gepp, Mrs. A. 26 West Park-gardens, Kew.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1905. §Gibbs, Miss Lilian S., F.L.S. 22 South-street, Thurloe-square, S.W.
1902. ‡Gibson, Andrew. 14 Cliftonville-avenue, Belfast.
1901. §Gibson, Professor George A., M.A. 8 Sandyford-place, Glasgow.
1876. *Gibson, George Alexander, M.D., D.Sc., LL.D., F.R.S.E. 3 Drumsheugh-gardens, Edinburgh.
1904. *Gibson, Mrs. Margaret D., LL.D. Castle Brae, Chesterton-lane, Cambridge.
1896. ‡Gibson, R. J. Harvey, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1887. *Giffen, Sir Robert, K.C.B., LL.D., F.R.S., V.P.S.S. (Pres. F, 1887, 1901.) Chanctonbury, Hayward's Heath.
1898. *Gifford, J. William. Oaklands, Chard.
1883. §Gilbert, Lady. Park View, Englefield Green, Surrey.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡Gilchrist, J. D. F., M.A., Ph.D., B.Sc., F.L.S. Marine Biologist's Office, Department of Agriculture, Cape Town.
1896. *Gilchrist, Percy C., F.R.S., M.Inst.C.E. Reform Club, Pall Mall, S.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *Gill, Sir David, K.C.B., LL.D., F.R.S., Hon.F.R.S.E. (President.) 34 De Vere-gardens, Kensington, W.
1902. ‡Gill, James F. 72 Strand-road, Bootle, Liverpool.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1907. §Gilmour, S. C. 3 Vernon-chambers, Southampton-row, W.C.
1893. *Gimingham, Edward. 21 Stamford Hill-mansions, Stamford Hill, N.
1904. ‡Ginn, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1900. ‡Ginsburg, Benedict W., M.A., LL.D. Cookham, Berks.
1884. ‡Girdwood, G. P., M.D. 28 Beaver Hall-terrace, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Caragana Lodge, Ladysmith, Vancouver Island, Canada.
1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
1871. *Glaisher, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890; Council, 1878–86.) Trinity College, Cambridge.
1880. *Glantawe, Right Hon. Lord. The Grange, Swansea.
1881. *Glazebrook, R. T., M.A., D.Sc., F.R.S. (Pres. A, 1893; Council, 1890–94, 1905–), Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
Glover, Thomas. 124 Manchester-road, Southport.
1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
1880. ‡Godman, F. Du Cane, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.

Year of Election.

1879. ‡Godwin-Austen, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883.) Nore, Godalming.
1878. ‡Goff, James (Local Sec. 1878). 29 Lower Leeson-street, Dublin.
1906. ‡Goldie, Sir George D. T., K.C.M.G., D.C.L., F.R.S. (Pres. E, 1906; Council, 1906-07.) 44 Rutland-gate, S.W.
1898. ‡Goldney, F. Bennett, F.S.A. Goodnestone Park, Dover.
1886. ‡Goldsmid, Major-General Sir F. J., K.C.S.I., C.B., F.R.G.S. (Pres. E, 1886.) 29 Phœnix Lodge-mansions, Brook Green, W.
1899. ‡Gomme, G. L., F.S.A. 24 Dorset-square, N.W.
1890. *Gonner, E. C. K., M.A. (Pres. F, 1897), Professor of Political Economy in the University of Liverpool.
1884. *Goodridge, Richard E. W. Hibbing, Minnesota, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1905. ‡Goold-Adams, Major Sir H. J., G.C.M.G., C.B. Government House, Bloemfontein, South Africa.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.
1893. ‡Gordon, Mrs. M. M. Ogilvie, D.Sc. 1 Rubislaw-terrace, Aberdeen.
1901. ‡Gorst, Right Hon. Sir John E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901.) 21 Victoria-square, S.W.
1875. *Gotch, Francis, M.A., D.Sc., F.R.S. (Pres. I, 1906; Council, 1901-07), Professor of Physiology in the University of Oxford. The Lawn, Banbury-road, Oxford.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1901. ‡Gourlay, Robert. Glasgow.
1901. §Gow, Leonard. Hayston, Kelvinside, Glasgow.
1876. ‡Gow, Robert. Cairndowan, Dowanhill-gardens, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill-gardens, Glasgow.
1873. ‡Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1902. *Graham, William, M.D. District Lunatic Asylum, Belfast.
1875. ‡Grahame, James (Local Sec. 1876). Care of Messrs. Grahame, Crums, & Connal, 34 West George-street, Glasgow.
1904. §Gramont, Comte Arnaud de. 179 rue de l'Université, Paris.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1905. §Grant-Dalton, Alan. Arundel, Rondebosch, Cape Colony.
1905. ‡Graumann, Harry. P.O. Box 2115, Johannesburg.
1890. ‡Gray, Andrew, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1905. ‡Gray, C. J. P.O. Box 208, Pietermaritzburg, South Africa.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A. 99 Grosvenor-road, S.W.
1904. ‡Gray, Rev. H. B., D.D. The College, Bradfield, Berkshire.
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
1904. ‡Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. §Gray, John, B.Sc. 9 Park-hill, Clapham Park, S.W.
1887. ‡Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1901. ‡Gray, R. W. 7 Orme-court, Bayswater, W.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.

Year of
Election.

1872. *Grece, Clair J., LL.D. 146 Station-road, Redhill, Surrey.
1905. ‡Green, A. F. Sea Point, Cape Colony.
1904. **Green, A. G. 2 Dartmouth-road, Brondesbury, N.W.*
1904. §Green, F. W. St. John's College, Cambridge.
1906. §Green, Professor J. A. The University, Sheffield.
1888. §GREEN, J. REYNOLDS, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1902), Professor of Botany to the Pharmaceutical Society of Great Britain. Downing College, Cambridge.
1903. ‡Green, W. J. 76 Alexandra-road, N.W.
1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 1 Staple Inn, W.C.
1905. ‡Greenhill, Henry H. P.O. Box 172, Bloemfontein, South Africa.
1905. ‡Greenhill, William. 6A George-street, Edinburgh.
1898. *GREENLY, EDWARD. Achnashean, near Bangor, North Wales.
1906. ‡Greenwood, Hamar, M.P. National Liberal Club, Whitehall-place, S.W.
1894. *GREGORY, J. WALTER, D.Sc., F.R.S., F.G.S. (Pres. C, 1907), Professor of Geology in the University of Glasgow.
1896. *GREGORY, Professor R. A., F.R.A.S. Dell Quay House, near Chichester.
1904. *Gregory, R. P. St. John's College, Cambridge.
1881. ‡Gregson, William, F.G.S. 106 Victoria-road, Darlington.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Cathedral-gardens, Trynampot, Madras.
1884. ‡GRIFFITHS, E. H., M.A., D.Sc., F.R.S. (Pres. A, 1906), Principal of University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1903. ‡Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
1888. *Grimshaw, James Walter, M.Inst.C.E. St. Stephen's Club, Westminster, S.W.
1894. ‡GROOM, Professor P., M.A., F.L.S. Hollywood, Egham, Surrey.
1894. ‡Groom, T. T., M.A., D.Sc., F.G.S., Professor of Geology in the University of Birmingham.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1904. ‡Grosvenor, G. H. New College, Oxford.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Rockdale, Orwell-road, Rathgar, Dublin.
1897. ‡Grünbaum, A. S., M.A., M.D. 45 Ladbroke-grove, W.
1887. ‡GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1905. *Gunn, Donald. Royal Societies Club, St. James's-street, S.W.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., F.L.S., F.Z.S. (Pres. D, 1880.) 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. §Gurney, Eustace. Sprowston Hall, Norwich.
1902. *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
1904. §Guttmann, Leo F., Ph.D. 18 Aberdare-gardens, N.W.

1905. §Hacker, Rev. W. J. Edendale, Pietermaritzburg, South Africa.
1881. *HADDON, ALFRED CORT, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902, 1905; Council, 1902– .) Inisfail, Hills-road, Cambridge.

Year of Election.

1905. ‡Haddon, Miss. Inisfail, Hills-road, Cambridge.
1888. *Hadfield, R. A., M.Inst.C.E. Parkhead House, Sheffield.
1905. ‡Hahn, Professor P. D., M.A., Ph.D. York House, Gardens, Cape Town.
1906. ‡Hake, George W. Oxford, Ohio, U.S.A.
1899. ‡HALL, A. D., M.A., Director of the Rothamsted Experimental Station, Harpenden, Herts.
1903. ‡HALL, E. MARSHALL, K.C. 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. 63 Belmont-street, Southport.
1854. *HALL, HUGH FERGIE, F.G.S. Cissbury Court, West Worthing, Sussex.
1899. ‡Hall, John, M.D. National Bank of Scotland, 37 Nicholas-lane, E.C.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1891. *Hallett, George. Cranford, Victoria-road, Penarth.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., LL.D., F.R.S. (Pres. I, 1902; Council, 1897–1903), Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, N.W.
1905. ‡Halliburton, Mrs. Church Cottage, 17 Marylebone-road, N.W.
1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1906. ‡Hamill, John Molyneux, M.A., M.B. 14 South-parade, Chiswick.
1906. ‡Hamilton, Charles I. 88 Twyford-avenue, Acton.
1885. ‡Hamilton, David James. 35 Queen's-road, Aberdeen.
1902. ‡HAMILTON, Rev. T., D.D. Queen's College, Belfast.
1905. ‡Hammersley-Heenan, R. H., M.Inst.C.E. Harbour Board Offices, Cape Town.
1905. ‡Hammond, Miss Edith. High Dene, Woldingham, Surrey.
1881. *HAMMOND, ROBERT, M.Inst.C.E. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
1905. *Hancock, Strangman. Plas Uchaf, Abergele, North Wales.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1906. §Hanson, David. Salterlee, Halifax, Yorkshire.
1904. §Hanson, E. K. University College, Reading.
1902. ‡Harbison, Adam, B.A. 5 Ravenhill-terrace, Ravenhill-road, Belfast.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., V.P.C.S. (GEN. SEC. 1883–97; Pres. B, 1875; Council, 1881–83.) St. Clare, Ryde, Isle of Wight.
1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1902. *HARDCASTLE, Miss FRANCES. 25 Boundary-road, N.W.
1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
1892. *HARDEN, ARTHUR, Ph.D., M.Sc. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
1905. ‡Hardie, Miss Mabel, M.B. High-lane, viâ Stockport.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. *HARKER, ALFRED, M.A., F.R.S., F.G.S. St. John's College, Cambridge.

Year of Election.

1896. ‡Harker, Dr. John Allen. National Physical Laboratory, Bushy House, Teddington.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1905. ‡Harland, H. C. P.O. Box 1024, Johannesburg.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest-hill, S.E.
1862. *Harley, Rev. Robert, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest-hill, S.E.
1868. *Harmer, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sidney F., M.A., Sc.D., F.R.S. King's College, Cambridge.
1906. ‡Harper, J. B. 16 St. George's-place, York.
1884. ‡Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.
1889. ‡Harris, H. Graham, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1903. ‡Harris, Robert, M.B. 18 Duke-street, Southport.
1904. ‡Harrison, Frank L. 83 Clarkehouse-road, Sheffield.
1904. ‡Harrison, H. Spencer. The Horniman Museum, Forest-hill, S.E.
1892. ‡Harrison, John (Local Sec. 1892). Rockville, Napier-road, Edinburgh.
1870. ‡Harrison, Reginald, F.R.C.S. (Local Sec. 1870.) 6 Lower Berkeley-street, Portman-square, W.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1901. *Harrison, W. E. 15 Lansdowne-road, Handsworth, Staffordshire.
1886. ‡Harrison, W. Jerome, F.G.S. Science Laboratory, Icknield-street Council School, Birmingham.
1885. ‡Hart, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1907. §Hart, W. E. Kilderry, near Londonderry.
1893. *Hartland, E. Sidney, F.S.A. (Pres. H, 1906; Council, 1906– .) Highgarth, Gloucester.
1905. ‡Hartland, Miss. Highgarth, Gloucester.
1871. *Hartley, Walter Noel, D.Sc., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1903), Professor of Chemistry in the Royal College of Science, Dublin. 10 Elgin-road, Dublin.
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡Hartog, P. J., B.Sc. University of London, South Kensington, S.W.
1905. ‡Harvey-Hogan, J. P.O. Box 1277, Johannesburg.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
1903. §Hastie, William. 20 Elswick-row, Newcastle-on-Tyne.
1904. ‡Hastings, G. 15 Oak-lane, Bradford, Yorkshire.
1875. *Hastings, G. W. (Pres. F, 1880.) Chapel House, Chipping Norton.
1903. §Hastings, W. G. W. 2 Halsey-street, Cadogan-gardens, S.W.
1889. ‡Hatch, F. H., Ph.D., F.G.S. Cowley Place, Cowley, Middlesex.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1904. ‡Havilland, Hugh de. Eton College, Windsor.

Year of Election.

1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. (Council, 1881–87.) 22 Down-street, W., and 33 Great George-street, S.W.
1897. §HAWKSLEY, CHARLES, M.Inst.C.E., F.G.S. (Pres. G, 1903; Council, 1902– .) 30 Great George-street, S.W.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., G.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *HAYCROFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
1900. §Hayden, H. H., B.A., F.G.S. Geological Survey, Calcutta, India.
1903. *Haydock, Arthur. 197 Preston New-road, Blackburn.
1903. ‡Hayward, Joseph William, M.Sc. 29 Deodar-road, Putney, S.W.
1896. *Haywood, Lieut.-Colonel A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A., F.R.S. Greyfriars, Southwold, Suffolk.
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W.
1902. ‡Heathorn, Captain T. B., R.A. 10 Wilton-place, Knightsbridge, S.W.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1892. *HEATON, WILLIAM H., M.A. (Local Sec. 1893), Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West, I.S.O. 12 Tring-avenue, Ealing, W.
1888. *Heawood, Edward, M.A. Briarfield, Church-hill, Merstham, Surrey.
1888. *Heawood, Percy J., Lecturer in Mathematics in Durham University. 41 Old Elvet, Durham.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E. 64 Victoria-street, S.W.
1901. *Heller, W. M., B.Sc. 40 Upper Sackville-street, Dublin.
1905. ‡Hellman, Hugo. Rand Club, Johannesburg.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1899. ‡Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1901. ‡Henderson, Rev. Andrew, LL.D. Castle Head, Paisley.
1905. *Henderson, Andrew. 17 Belhaven-terrace, Glasgow.
1905. *Henderson, Miss Catharine. 17 Belhaven-terrace, Glasgow.
1891. *HENDERSON, G. G., D.Sc., M.A., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College, Glasgow.
1907. §Henderson, H. F. 46 Clarendon Park-road, Leicester.
1905. §Henderson, Mrs. Technical College, Glasgow.
1906. ‡Henderson, J. B., D.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1880. *Henderson, Vice-Admiral W. H., R.N. 12 Vicarage-gardens, Campden Hill, W.
1904. *Hendrick, James. Marischal College, Aberdeen.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883–89), Professor of Mechanics and Mathematics in the City and Guilds of London Institute, Central Institution, Exhibition-road. S.W. 34 Clarendon-road, Notting Hill, W.
1906. §Henry, Dr. T. A. Imperial Institute, S.W.

Year of
Election.

1892. ‡HEPBURN, DAVID, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1904. §Hepworth, Commander M. W. C., C.B., R.N.R. Meteorological Office, Victoria-street, S.W.
1892. *HERBERTSON, ANDREW J., Ph.D., F.R.S.E., F.R.G.S. 4 Broad-street, Oxford.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. Irrigation and Water Supply Department, Pretoria.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., Pres.L.S. (GENERAL SECRETARY, 1903– ; Pres. D, 1895; Council, 1894–1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
1908. *Herring, Dr. Percy T., Physiological Department. The University, Edinburgh.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, Rev. J. C. W. Bracknell, Berkshire.
1905. ‡Hervey, Miss Mary F. S. 22 Morpeth-mansions, S.W.
1903. *HESKETH, CHARLES H. FLEETWOOD, M.A. The Rookery, North Meols, Southport.
1895. §Hesketh, James. Scarisbrick Avenue-buildings, 233 Lord-street, Southport.
1905. ‡Hewat, M. L., M.D. Mowbray, near Cape Town, South Africa.
1894. ‡HEWETSON, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. ‡Hewins, W. A. S., M.A., F.S.S. The Rowans, Putney Lower Common, S.W.
1896. §Hewitt, David Basil, M.D. Oakleigh, Northwich, Cheshire.
1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D. 8 Montpelier-road, Twickenham.
1882. *HEYCOCK, CHARLES T., M.A., F.R.S. King's College, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. St. Barnabas Vicarage, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.
1886. ‡HEYWOOD, HENRY, J.P. Witla Court, near Cardiff.
1898. ‡Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, W. M., M.A., D.Sc., F.R.S. (Pres. A, 1895). Professor of Physics in the University of Sheffield. Leamhurst, Ivy Park-road, Sheffield.
1886. ‡Hicks, Mrs. W. M. Leamhurst, Ivy Park-road, Sheffield.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S. (Pres. D, 1903), Professor of Zoology in Victoria University, Manchester.
1864. *HIERN, W. P., M.A., F.R.S. The Castle, Barnstaple.
1891. ‡HIGGS, HENRY, LL.B., F.S.S. (Pres. F, 1899; Council, 1904–06). H.M. Treasury, Whitehall, S.W.
1907. §HILEY, E. V. (Local Sec. 1907.) Town Hall, Leicester.
1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.
1903. *Hill, Arthur W. King's College, Cambridge.
1906. §Hill, Charles A., M.A., M.B. 13 Rodney-street, Liverpool.
1881. *HILL, Rev. EDWIN, M.A. The Rectory, Cockfield, Bury St. Edmunds.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.

Year of Election.

1898. *Hill, Thomas Sidney. 80 Harvard-court, West End-lane, N.W.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in the University of Birmingham. 43 Calthorpe-road, Edgbaston, Birmingham.
1907. *Hills, Major E. H., C.M.G., R.E., F.R.G.S. 32 Prince's-gardens, S.W.
1903. *Hilton, Harold, Glencairn, Platt's-lane, Hampstead, N.W.
1903. *HIND, WHEELTON, M.D., F.G.S. Roxeth House, Stoke-on-Trent.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1906. *Hingston, Miss A. Clarence Cottage, Clare-road, Cambridge.
1900. §Hinks, Arthur R., M.A. The Observatory, Cambridge.
1903. *Hinmers, Edward. Glentwood, South Downs-drive, Hale, Cheshire.
1899. ‡Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1887. *Hobson, Bernard, M.Sc., F.G.S. Thornton, Didsbury, near Manchester.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1904. §Hobson, Ernest William, Sc.D., F.R.S. The Gables, Mount Pleasant, Cambridge.
1907. §Hobson, Mrs. Mary. 6 Hopefield-avenue, Belfast.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology in the Victoria University, Manchester. 18 St. John-street, Manchester.
1880. ‡Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glenluce-road, Blackheath, S.E.
1905. ‡Hodgson, Ven. Archdeacon R. The Rectory, Wolverhampton.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1904. §Hodson, F. Bedale's School, Petersfield, Hampshire.
1904. ‡HOGARTH, D. G., M.A. (Pres. H, 1907; Council, 1907–) Chapel Meadow, Forest Row, Sussex.
1894. ‡*Hogg, A. F., M.A.* 13 *Victoria-road, Darlington.*
1908. §Hogg, Right Hon. Jonathan. Stratford, Rathgar, Co. Dublin.
1907. §Holden, Colonel H. C. L., R.A., F.R.S. Gifford House, Blackheath, S.E.
1883. ‡Holden, John J. 73 Albert-road, Southport.
1887. *Holder, Henry William, M.A. Sheet, near Petersfield.
1900. ‡HOLDICH, Colonel Sir THOMAS H., R.E., K.C.B., K.C.I.E., F.R.G.S. (Pres. E, 1902.) 41 Courtfield-road, S.W.
1887. *Holdsworth, C. J. Fernhill, Alderley Edge, Cheshire.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. §Holland, J. L., B.A. 72 Kingsley Park-terrace, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡Holland, Thomas H., F.R.S., F.G.S. Geological Survey Office, Calcutta.
1889. ‡Holländer, Bernard, M.D. 35A Welbeck-street, W.
1906. *Hollingworth, Miss. Leithen, Newnham-road, Bedford.
1905. ‡Hollway, H. C. Schunke. Plaisir de Merle, P.O. Simondium, viâ Paarl, South Africa.
1883. *Holmes, Mrs. Basil. 23 Corfton-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 36 Buckingham-mansions, West End-lane, N.W.

Year of Election.

1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1903. *Holt, Alfred, jun. Crofton, Aigburth, Liverpool.
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford. Bonchurch Lodge, Barnet.
1847. ‡HOOKER, Sir JOSEPH DALTON, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (PRESIDENT, 1868; Pres. E, 1881; Council, 1866–67.) The Camp, Sunningdale, Berkshire.
1892. ‡HOOKER, REGINALD H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. ‡Hopewell-Smith, A., M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
1905. *Hopkins, Charles Hadley. Junior Constitutional Club. 101 Piccadilly, W.
1901. *Hopkinson, Bertram, M.A., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Adams-road, Cambridge.
1884. *HOPKINSON, CHARLES (Local Sec. 1887). The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *HOPKINSON, JOHN, Assoc.M.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. 84 New Bond-street, W.; and Weetwood, Watford.
1905. ‡Hopkinson, Mrs. John. Holmwood, Wimbledon Common, S.W.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1885. ‡HORNE, JOHN, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1903. ‡Horne, William, F.G.S. Leyburn, Yorkshire.
1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1905. *Horsburgh, E. M., M.A., B.Sc., Lecturer in Technical Mathematics in the University of Edinburgh.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, Sir VICTOR A. H., LL.D., B.Sc., F.R.S., F.R.C.S. (Council, 1893–98.) 25 Cavendish-square, W.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T., F.G.S. 45 Newmarket-road, Norwich.
1906. *Hough, Miss Ethel M. Codsall Wood, near Wolverhampton.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S., M.A., F.R.S., F.R.A.S., His Majesty's Astronomer at the Cape of Good Hope. Royal Observatory, Cape Town.
1905. §Houghting, A. G. L. Glenelg, Musgrave-road, Durban, Natal.
1905. ‡Houseman, C. L. P.O. Box 149, Johannesburg.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, S.E.
1904. *Howard, Mrs. G. L. C. Agricultural Research Institute, Pusa, Bengal, India.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1901. §Howarth, E., F.R.A.S. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Somerley, Rawson-avenue, Halifax.
1907. §Howarth, O. J. R., M.A. 25 St. Leonard's-terrace, Chelsea, S.W.
1905. ‡Howick, Dr. W. P.O. Box 503, Johannesburg.
1901. ‡Howie, Robert Y. 3 Greenlaw-avenue, Paisley.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. 7 Prince's-buildings, Clifton, Bristol.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.

Year of Election.

1887. §HOYLE, WILLIAM E., M.A., D.Sc. (Pres. D, 1907.) Victoria University, Manchester.

1903. ‡Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.

1898. §HUDLESTON, W. H., M.A., F.R.S., F.G.S. (Pres. C, 1898.) 8 Stanhope-gardens, S.W.

1898. ‡Hudson, Mrs. Sunny Bank, Egerton, Huddersfield.

1867. *HUDSON, WILLIAM H. H., M.A. 34 Birdhurst-road, Croydon.

1858. *HUGGINS, Sir WILLIAM, K.C.B., D.C.L., LL.D., F.R.S., F.R.A.S. (PRESIDENT, 1891; Council, 1868–74, 1876–84.) 90 Upper Tulse-hill, S.W.

1871. *Hughes, George Pringle, J.P., F.R.G.S. Middleton Hall, Wooler, Northumberland.

1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S. (Council, 1879–86), Woodwardian Professor of Geology in the University of Cambridge. Ravensworth, Brooklands-avenue, Cambridge.

1867. ‡HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874.) 14 Stanley-gardens, Notting Hill, W.

1903. ‡Hulton, Campbell G. Palace Hotel, Southport.

1905. §Hume, D. G. W. P.O. Box 1132, Johannesburg.

1901. ‡Hume, John H. Toronto, Canada; and 63 Bridgegate, Irvine.

1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.

1907. §Humphries, Albert E. Coxe's Lock Mills, Weybridge.

1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.

1891. *Hunt, Cecil Arthur, Southwood, Torquay.

1881. ‡Hunter, F. W. 16 Old Elvet, Durham.

1889. ‡Hunter, Mrs. F. W. 16 Old Elvet, Durham.

1901. *Hunter, William. Evirallan, Stirling.

1903. ‡Hurst, Charles C., F.L.S. Burbage, Hinckley.

1882. *Hurst, Walter, M.D., B.Sc. 210 Seventh-avenue, San Francisco, U.S.A.

1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.

1905. ‡Hutcheon, Duncan, M.R.C.V.S., Department of Agriculture, Cape Town.

1894. *HUTCHINSON, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.

1903. §Hutchinson, Rev. H. N. 17 St. John's Wood Park, Finchley-road, N.W.

Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.

1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.

1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.

1901. *Hutton, R. S., M.Sc. The Victoria University, Manchester.

1883. ‡Hyde, George H. 23 Arbour-street, Southport.

1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.

1900. *Hyndman, H. H. Francis. 27 Pembroke-square, W.

1883. ‡Idris, T. H. W. 110 Pratt-street, Camden Town, N.W.

Ihne, William, Ph.D. Heidelberg.

1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.

1906. ‡Iliffe, J. W. Oak Tower, Upperthorpe, Sheffield.

1885. ‡im Thurn, Sir Everard F., C.B., K.C.M.G. Colombo, Ceylon.

1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.

1907. §Ingham, Charles B. Moira House, Eastbourne.

Year of Election.

1905. ‡Ingham, W. Engineer's Office, Sand River, Uitenhage.
1893. ‡Ingle, Herbert. Department of Agriculture, Pretoria.
1901. ‡INGLIS, JOHN, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1905. §Innes, R. T. A., F.R.A.S. Meteorological Observatory, Johannesburg.
1901. *Ionides, Stephen A. 37 Moscow-court, Bayswater, W.
1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1903. ‡Irving, W. B. 27 Park-road, Southport.
1908. §Irwin, Alderman John. 33 Rutland-square, Dublin.
1905. ‡*Iwasaki, Koyata. Pembroke College, Cambridge.*

1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The University, Glasgow.
1883. *Jackson, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. §Jackson, C. S. 25 Nightingale-place, Woolwich, S.E.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Somenos, Vancouver Island, B.C., Canada.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1897. §Jackson, James, F.R.Met.Soc. Seabank, Girvan, N.B.
1906. *Jackson, James Thomas, M.A. Engineering School, Trinity College, Dublin.
1898. *Jackson, Sir John. 51 Victoria-street, S.W.
1905. ‡Jacobsohn, Lewis B. Lloyd's-buildings, 58 Burg-street, Cape Town.
1905. ‡Jacobsohn, Sydney Samuel. Lloyd's-buildings, 58 Burg-street, Cape Town.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1905. *Jaffé, Arthur, B.A. Strandtown, Belfast.
1874. *Jaffé, John. Villa Jaffé, 38 Promenade des Anglais, Nice, France.
1905. ‡Jagger, J. W. St. George's-street, Cape Town.
1906. ‡Jalland, W. H. Museum-street, York.
1891. *James, Charles Henry, J.P. 64 Park-place, Cardiff.
1891. *James, Charles Russell. 5 Raymond-buildings, Gray's Inn, W.C.
1904. ‡James, Thomas Campbell. University College, Aberystwyth.
1905. ‡Jameson, Adam. Office of the Commissioner of Lands, Pretoria.
1896. *Jameson, H. Lyster, M.A., Ph.D. Transvaal Technical Institute, Johannesburg.
1881. ‡Jamieson, Andrew, M.Inst.C.E., F.R.S.E., Principal of the College of Science and Arts, Glasgow.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1903. ‡JARRATT, J. ERNEST. (Local Sec. 1903.) 10 Cambridge-road, Southport.
1904. *Jeans, J. H., M.A., F.R.S., Professor of Applied Mathematics in Princeton University, Princeton, New Jersey, U.S.A.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1903. ‡Jenkinson, J. W. The Museum, Oxford.
1904. ‡Jenkinson, W. W. 6 Moorgate-street, E.C.
1893. §Jennings, G. E. Glen Helen, Narborough-road, Leicester.
1905. ‡Jennings, Sydney. P.O. Box, 149 Johannesburg.
1905. ‡Jerome, Charles. P.O. Box 83, Johannesburg.

Year of
Election.

1887. ‡Jervis-Smith, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1900. *Jevons, H. Stanley, M.A., B.Sc. Llanishen, near Cardiff.
1907. *Jevons, Miss H. W. 19 Chesterford-gardens, Hampstead, N.W.
1905. §Jeyes, Miss Gertrude, B.A. Berrymead, 6 Lichfield-road, Kew Gardens.
1905. ‡Jobson, J. B. P.O. Box 3341, Johannesburg.
1884. ‡Johnson, Alexander, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W., B.A., B.Sc. Archbishop Holgate's Grammar School, York.
1898. *Johnson, W. Claude, M.Inst.C.E. Broadstone, Coleman's Hatch, Sussex.
1899. §Johnston, Colonel Sir Duncan A., K.C.M.G., C.B., R.E. Ordnance Survey, Southampton.
1883. ‡Johnston, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. 27 Chester-terrace, Regent's Park, N.W.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡Johnston-Lavis, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1888. ‡Joly, John, M.A., D.Sc., F.R.S., F.G.S., Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1887. ‡Jones, D. E., B.Sc. Inglewood, Four Oaks, Sutton Coldfield.
1904. §Jones, Miss E. E. Constance. Girton College, Cambridge.
1890. §Jones, Rev. Edward, F.G.S. Primrose Cottage, Embsay, Skipton.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. §Jones, Evan. Ty-Mawr, Aberdare.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *Jones, Rev. G. Hartwell, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1903. *Jones, H. O., M.A. Clare College, Cambridge.
1901. §Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1905. ‡Jones, Miss Parnell. The Rectory, Llanddewi Skirrid, Abergavenny, Monmouthshire.
1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S. (Pres. C, 1891.) Penbryn, Chesham Bois-lane, Chesham, Bucks.
1875. *Jose, J. E. Ethersall, Tarbock-road, Huyton, Lancashire.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, Hon. Mrs. St. John's Croft, Winchester.
1905. ‡Judd, Miss Hilda M., B.Sc. Berrymead, 6 Lichfield-road, Kew.
1870. ‡Judd, John Wesley, C.B., LL.D., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886–92.) Orford Lodge, 30 Cumberland-road, Kew.
1903. §Julian, Henry Forbes. Redholme, Braddon's Hill-road, Torquay.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1905. §Juritz, C. F., M.A., F.I.C. Government Analytical Laboratory, Parliament-street, Cape Town.

Year of Election.

1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. Pen-y-Coed, Pritchatts-road, Birmingham.
1904. ‡Kayser, Professor H. The University, Bonn, Germany.
1892. ‡KEANE, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1878. *Kelland, W. H. 80 Lothian-road, S.W.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898–1904.) 1 Savile-row, W.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1893. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1891. ‡KENDALL, PERCY F., M.Sc., F.G.S., Professor of Geology in the University of Leeds.
1875. ‡KENNEDY, Sir ALEXANDER B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) 1 Queen Anne-street, Cavendish-square, W.
1906. ‡Kennedy, Alfred Joseph, F.R.G.S. Care of Williams Deacon's Bank, Ltd., 2 Cockspur-street, S.W.
1897. §Kennedy, George, M.A., LL.D., K.C. Crown Lands Department, Toronto, Canada.
1906. ‡Kennedy, Robert Sinclair. Glengall Ironworks, Millwall, E.
1905. *Kennerley, W. R. P.O. Box 158, Pretoria.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.
1901. ‡Kent, G. 16 Premier-road, Nottingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1892. ‡KERR, J. GRAHAM, M.A., Professor of Natural History in the University, Glasgow.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1869. *Kesselmeyer, Charles Augustus. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Elysée Villa, Manchester-road, Altrincham, Cheshire.
1903. §Kewley, James. Balek Papan, Koltei, Dutch Borneo.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1905. ‡Kidd, Professor A. Stanley. Rhodes University College, Grahamstown, Cape Colony.
1902. §Kidd, George. Greenhaven, Malone Park, Belfast.
1906. §Kidner, Henry, F.G.S. 78 Gladstone-road, Watford.
1886. §KIDSTON, ROBERT, F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1901. *Kiep, J. N. 4 Hughenden-terrace, Kelvinside, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡KIMMINS, C. W., M.A., D.Sc. Dame Armstrong House, Harrow.
1905. §Kincaid, Major-General W. Care of Messrs, Alexander, Fletcher, & Co., 2 St. Helen's-place, Bishopsgate-street, E.C.
1905. §Kincaid, Mrs. Care of Messrs. Alexander, Fletcher, & Co., 2 St. Helen's-place, Bishopsgate-street, E.C.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1872. *King, Mrs. E. M. Melrose, Alachua, Co. Florida, U.S.A.

Year of Election.

1888. *King, E. Powell. Wainsford, Lymington, Hants.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1899. ‡KING, Sir GEORGE, K.C.I.E., F.R.S. (Pres. K, 1899.) Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1883. *King, John Godwin. Stonelands, West Hoathly.
1883. *King, Joseph. Sandhouse, Witley, Godalming.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William, M.Inst.C.E. 5 Beach-lawn, Waterloo, Liverpool.
1903. §Kingsford, H. S., M.A. Royal Anthropological Institute, 3 Hanover-square, W.
1900. ‡KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. University College, Nottingham.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1907. §Kirby, William Forsell, F.L.S. Hilden, 18 Sutton Court-road, Chiswick, W.
1905. ‡Kirkby, Reginald G. P.O. Box 7, Pietermaritzburg, Natal.
1901. §Kitto, Edward. The Observatory, Falmouth.
1886. ‡Knight, Captain J. M., F.G.S. Bushwood, Wanstead, Essex.
1905. §Knightley, Lady, of Fawsley. Fawsley Park, Daventry.
1888. ‡KNOTT, Professor CARGILL G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Sunnybank, Wilmslow, Cheshire.
1887. *Knott, John F. St. Martin's, Hooton, near Chester.
1906. *Knowles, Arthur J., B.A., M.Inst.C.E. New Nile Bridge, Roda Island, Cairo, Egypt.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1903. ‡Knowlson, J. F. 26 Part-street, Southport.
1902. ‡KNOX, R. KYLE, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1905. ‡Koenig, J. P.O. Box 272, Cape Town.
1890. *Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.
1888 *Kunz, G. F., M.A., Ph.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.

1905. ‡Lacey, William. Champ d'Or Gold Mining Co., Luipaardsvlei, Transvaal.
1885. *Laing, J. Gerard. 5 Pump-court, Temple, E.C.
1904. ‡Lake, Philip. St. John's College, Cambridge.
1904. ‡Lamb, C. G. Ely Villa, Glisson-road, Cambridge.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Pure Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1903. ‡Lambert, Joseph. 9 Westmoreland-road, Southport.
1893. *LAMPLUGH, G. W., F.R.S., F.G.S. (Pres. C, 1906.) 13 Beaconsfield-road, St. Albans.
1905. ‡Lane, Rev. C. A. P.O. Box 326, Johannesburg.
1898. *LANG, WILLIAM H. 61 Gibson-street, Hillhead, Glasgow.
1905. §Lange, John H. Judges' Chambers, Kimberley.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904–07), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.

Year of
Election.

1865. ‡LANKESTER, Sir E. RAY, K.C.B., M.A., LL.D., D.Sc., F.R.S. (PRESIDENT, 1906; Pres. D, 1883; Council, 1889-90, 1894-95, 1900-02.) 29 Thurloe-place, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892), Professor of Geology and Physiography in the University of Birmingham. 48 Frederick-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., Sec.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. Longridge, Harrow.
1896. *Last, William I. Victoria and Albert Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. Parliament-mansions, Westminster, S.W.
1900. ‡Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1892. ‡LAURIE, MALCOLM, B.A., D.Sc., F.L.S. School of Medicine, Surgeons' Hall, Edinburgh.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia, Canada.
1907. *Laurie, Robert Douglas. 16 James-street, Birkenhead.
1870. *Law, Channell. Ilsham Dene, Torquay.
1884. ‡Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1907. §LAWFORD, JAMES. London City and Midland Bank, Leicester.
1905. §Lawrence, Miss M. Roedean School, near Brighton.
1888. §Layard, Miss Nina F. Rookwood, Tonnereau-road, Ipswich.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1894. *LEAHY, A. H., M.A., Professor of Mathematics in the University of Sheffield. 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1905. ‡Leake, E. O. 5 Harrison-street, Johannesburg.
1901. *Lean, George, B.Sc. 15 Park-terrace, Glasgow.
1904. *Leathem, J. G. St. John's College, Cambridge.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the Durham College of Science, Newcastle-on-Tyne.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1898. ‡LEE, ARTHUR, *J.P.* (*Local Sec.* 1898.) 10 *Berkeley-square, Clifton, Bristol.*
1907. §Lee, Mrs. Barton. 37 Derby-road, Heaton Moor, Stockport.
1896. §Lee, Rev. H. J. Barton. The Limes, Derby-road, Heaton Moor, Stockport.
1894. *Lee, Mrs. W. Ashdown House, Forest Row, Sussex.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1905. §Lees, Mrs. A. P. Care of Parr's Bank, York-street, Manchester.
1892. *LEES, CHARLES H., D.Sc., F.R.S., Professor of Physics in the East London College, Mile End. Greenacres, Mayfield-avenue, Woodford Green, Essex.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.
1906. ‡Lees, Robert. Victoria-street, Fraserburgh.

Year of Election.

1905. ‡Lees, R. Wilfrid. Pigg's Peak Development Co., Swaziland, South Africa.

*Leese, Joseph. 3 Lord-street West, Southport.

1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.

1906. ‡Leetham, Sidney. Elm Bank, York.

1881. ‡Le Feuvre, J. E. (Local Sec. 1882.) Southampton.

1905. ‡Legg, W. A. P.O. Box 1621, Cape Town.

1892. ‡Lehfeldt, Robert A. 56 *Norfolk-square. W.*

1891. ‡Leigh, W. W. Glyn Bargoed, Treharris, R.S.O., Glamorganshire.

1903. ‡Leighton, G. R., M.D., F.R.S.E., Professor of Pathology in the Royal Veterinary College, Edinburgh.

1906. ‡Leiper, Robert T., M.B., F.Z.S. London School of Tropical Medicine, Royal Albert Dock, E.

1905. §Leitch, Donald. P.O. Box 1703, Johannesburg.

1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.

1903. *Lempfert, R. G. K., M.A. Meteorological Office, 63 Victoria-street, S.W.

1902. ‡Lennox, R. N. Rosebank, Hammersmith, W.

1887. *Leon, John T. Elmwood, Grove-road, Southsea.

1901. §Leonard, J. H., B.Sc. 28 Talgarth-road, West Kensington, W.

1905. ‡Leonard, Right Rev. Bishop John. St. Mary's, Cape Town.

1904. ‡*Lepper, Alfred William.* 6 *Trinity College, Dublin.*

1890. *Lester, Joseph Henry, Royal Exchange, Manchester.

1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E.

1900. ‡Letts, Professor E. A., D.Sc., F.R.S.E. Queen's College, Belfast.

1896. §Lever, W. H. Thornton Manor, Thornton Hough, Cheshire.

1905. ‡Levin, Benjamin. P.O. Box 74, Cape Town.

1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.

1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.

1905. ‡Lewin, J. B. Duncan's-chambers, Shortmarket-street, Cape Town.

1904. *Lewis, Mrs. Agnes S., LL.D. Castle Brae, Chesterton-lane, Cambridge.

1870. ‡Lewis, Alfred Lionel. 35 Beddington-gardens, Wallington, Surrey.

1891. ‡Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.

1905. ‡Lewis, F. S., M.A. South African Public Library, Cape Town.

1904. ‡Lewis, Hugh. Glanafrau, Newtown, Montgomeryshire.

1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.

1903. §Lewkowitsch, Dr. J. 71 Priory-road, N.W.

1906. §Liddiard, James Edward, F.R.G.S. Rodborough Grange, Bournemouth.

1908. §Lilly, W. E., M.A., Sc.D. 39 Trinity College, Dublin.

1904. ‡Link, Charles W. 14 Chichester-road, Croydon.

1898. §Lippincott, R. C. Cann. Over Court, near Bristol.

1895. *Lister, The Right Hon. Lord, F.R.C.S., D.C.L., D.Sc., F.R.S. (President, 1896.) 12 Park-crescent, Portland-place, W.

1888. ‡Lister, J. J., M.A., F.R.S. (Pres. D, 1906.) St. John's College, Cambridge.

1861. *Liveing, G. D., M.A., F.R.S. (Pres. B, 1882; Council 1888–95; Local Sec. 1862), Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.

1876. *Liversidge, Archibald, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W. United University Club, Suffolk-street, Pall Mall, W.

Year of Election.

1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1903. §Lloyd, Godfrey I. H. 8 Claremont-place, Sheffield.
1891. *Lloyd, R. J., M.A., D.Litt., F.R.S.E. 49A Grove-street, Liverpool.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Wednesbury.
1854. *Lobley, J. Logan, F.G.S., F.R.G.S. 36 Palace-street, Buckingham Gate, S.W.
1892. ‡Loch, C. S., B.A. Denison House, Vauxhall Bridge-road, S.W.
1905. ‡Lochrane, Miss T. 8 Prince's-gardens, Dowanhill, Glasgow.
1904. ‡Lock, Rev. J. B. Herschel House, Cambridge.
1863. ‡Lockyer, Sir J. Norman, K.C.B., LL.D., D.Sc., F.R.S. (President, 1903; Council, 1871–76, 1901–02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1900. §Lockyer, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *Lodge, Alfred, M.A. The Croft, Peperharow-road, Godalming.
1875. *Lodge, Sir Oliver J., D.Sc., LL.D., F.R.S. (Pres. A, 1891; Council, 1891–97, 1899–1903), Principal of the University of Birmingham.
1894. *Lodge, Oliver W. F. 17 Ruskin-buildings, Westminster, S.W.
1896. §Lomas, J., F.G.S. 13 Moss-grove, Birkenhead.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. ‡Londonderry, The Marquess of, K.G. Londonderry House, Park-lane, W.
1903. ‡Long, Frederick. The Close, Norwich.
1905. §Long, W. F. City Engineer's Office, Cape Town.
1883. *Long, William. Thelwall Heys, near Warrington.
1904. *Longden, J. A., M.Inst.C.E. Stanton-by-Dale, Nottingham.
1905. §Longden, Mrs. J. B. Stanton-by-Dale, Nottingham.
1898. *Longfield, Miss Gertrude. Belmont, High Halstow, Rochester.
1901. *Longstaff, Frederick V., F.R.G.S. Ridgelands, Wimbledon, Surrey.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W.
1899. *Longstaff, Tom G., M.A., M.D. Ridgelands, Wimbledon, S.W.
1903. ‡Loton, John, M.A. 23 Hawkshead-street, Southport.
1897. ‡Loudon, James, LL.D., President of the University of Toronto, Canada.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §Louis, Henry, M.A., Professor of Mining in the Durham College of Science, Newcastle-on-Tyne.
1887. *Love, A. E. H., M.A., D.Sc., F.R.S. (Pres. A, 1907), Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1904. *Love, J. B. Outlands, Devonport.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1905. ‡Loveday, Professor T. South African College, Cape Town.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1905. ‡Lowe, E. C. Chamber of Trade, Johannesburg.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Spondon, Derbyshire.
1894. ‡Lowenthal, Miss Nellie. Woodside, Egerton, Huddersfield.
1903. *Lowry, Dr. T. Martin. 130 Horseferry-road, S.W.
1901. *Lucas, Keith. Greenhall, Forest Row, Sussex.
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1906. §Ludlam, Ernest Bowman. Ackworth School, Pontefract, Yorks.

Year of Election.

1866. *Lund, Charles. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1905. ‡Lunnon, F. J. P.O. Box 400, Pretoria.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S. 6 De Grey-road, Leeds.
1874. *LUPTON, SYDNEY, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1898. §Luxmoore, Dr. C. M. University College, Reading.
1903. ‡Lyddon, Ernest H. Lisvane, near Cardiff.
1884. ‡Lyman, H. H. 384 St. Paul-street, Montreal, Canada.
1907. *Lyons, Captain Henry George, R.E., D.Sc., F.R.S., Director-General of the Survey Department, Egypt. Gezira Gardens, Cairo, Egypt.

1905. ‡Maberly, Dr. John. Shirley House, Woodstock, Cape Colony.
1868. ‡MACALISTER, ALEXANDER, M.A., M.D., F.R.S. (Pres. H, 1892; Council, 1901-06), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, DONALD, M.A., M.D., LL.D., B.Sc., Principal of the University of Glasgow.
1904. ‡Macalister, Miss M. A. M. Torrisdale, Cambridge.
1896. ‡MACALLUM, Professor A. B., Ph.D., F.R.S. (Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1866. *M'Arthur, Alexander. 79 Holland-park, W.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. ‡MACBRIDE, Professor E. W., M.A., F.R.S. McGill University, Montreal, Canada.
1902. *Maccall, W. T., M.Sc. 223 Burrage-road, Plumstead.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1887. *McCarthy, James. Care of Sir Sherston Baker, Bart., 18 Cavendish-road, Regent's Park, N.W.
1904. §McClean, Frank Kennedy. Rusthall House, Tunbridge Wells.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1902. ‡McClelland, J. A., M.A., Professor of Physics in University College, Dublin.
1906. ‡McClure, Rev. E. 80 Eccleston-square, S.W.
1878. *M'Comas, Henry. Pembroke House, Pembroke-road, Dublin.
1901. *MacConkey, Alfred. Queensberry Lodge, Elstree, Herts.
1905. ‡McConnell, D. E. Montrose-avenue, Orangezicht, Cape Town.
1901. ‡MacCormac, J. M., M.D. 31 Victoria-place, Belfast.
1892. *McCowan, John, M.A., D.Sc. Henderson-street, Bridge of Allan, N.B.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1905. §McCulloch, Principal J. D. Free College, Edinburgh.
1904. ‡McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1904. ‡Macdonald, H. M., M.A., F.R.S., Professor of Mathematics in the University of Aberdeen.
1905. ‡McDonald, J. G. P.O. Box 67, Bulawayo.
1900. ‡MacDonald, J. Ramsay, M.P. 3 Lincoln's Inn-fields, W.C.
1890. *MacDonald, Mrs. J. Ramsay. 3 Lincoln's Inn-fields, W.C.
1905. §Macdonald, J. S., B.A., Professor of Physiology in the University of Sheffield.
1884. *Macdonald, Sir W. C. 449 Sherbrooke-street West, Montreal, Canada.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.

Year of Election.

1906. §McFarlane, John. 30 Parsonage-road, Withington, Manchester.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1905. ‡Macfarlane, T. J. M. P.O. Box 1198, Johannesburg.
1901. ‡Macfee, John. 5 Greenlaw-terrace, Paisley.
1888. ‡MacGeorge, James. 7 Stonor-road, Kensington, W.
1908. §McGrath, Joseph, LL.D. (Local Sec. 1908.) Royal University of Ireland, Dublin.
1906. §Macgregor, D. H., M.A. Trinity College, Cambridge.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh.
1902. ‡McIlroy, Archibald. Glenvale, Drumbo, Lisburn, Ireland.
1905. ‡Macindoe, Flowerdue. 23 Saratoga-avenue, Johannesburg.
1867. *McIntosh W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. §MacKay, A H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. ‡Mackay, John Yule, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903–), Professor of Physiology in the University of Glasgow. Maxieburn, Stonehaven, N.B.
1905. ‡McKenzie, A. R. P.O. Box 214, Cape Town.
1905. §Mackenzie, Hector. Standard Bank of South Africa, Cape Town.
1905. ‡*Mackenzie, J. 13 Derwent-road, Kloof-road, Cape Town.*
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1901. *Mackenzie, Thomas Brown. Netherby, Manse-road, Motherwell, N.B.
1872. *Mackey, J. A. United University Club, Pall Mall East, S.W.
1901. ‡Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡Mackinder, H. J., M.A., F.R.G.S. (Pres. E, 1895; Council, 1904–1905.) London School of Economics, Clare Market, W.C.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1894. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 11 Leopold-place, Edinburgh.
1901. ‡Maclaren, J. Malcolm. Royal Colonial Institute, Northumberland Avenue, W.C.
1905. ‡McLaren, Thomas. P.O. Box 1034, Johannesburg.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. ‡McLean, Angus, B.Sc. Ascog, Meikleriggs, Paisley.
1905. ‡*MacLean, Lachlan. Greenhill, Kenilworth, Cape Colony.*
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1905. *Maclear, Admiral J. P. Beaconscroft, Chiddingfold, Godalming.
1868. §McLeod, Herbert, F.R.S. (Pres. B, 1892; Council, 1885–90.) 9 Coverdale, Richmond, Surrey.
1883. ‡MacMahon, Major Percy A., R.A., D.Sc., F.R.S. (General Secretary, 1902– ; Pres. A, 1901; Council, 1898–1902.) 27 Evelyn-mansions, Carlisle-place, S.W.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1905. ‡MacNay, Arthur. Cape Government Railway Offices, De Aar, Cape Colony.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1905. §Macphail, Dr. S. Rutherford. Rowditch, Derby.
1905. ‡Macrae, Harold J. P.O. Box 817, Johannesburg.

Year of Election.

1907. §Macrosty, Henry W. 29 Hervey-road, Blackheath, S.E.
1906. §Macturk, G. W. B. 15 Bowlalley-lane, Hull.
1908. §McWalter, J. C., M.D., M.A. 19 North Earl-street, Dublin.
1902. ‡McWeeney, E. J., M.D. 84 Stephen's-green, Dublin.
1902. ‡McWhirter, William. 9 Walworth-terrace, Glasgow.
1908. §Madden, Rt. Hon. Mr. Justice. Nutley Booterstown, Dublin.
1905. §Magenis, Lady Louisa. 34 Lennox-gardens, S.W.
1902. ‡Magill, R., M.A., Ph.D. The Manse, Maghera, Co. Derry.
1875. *Magnus, Sir Philip, B.Sc., B.A., M.P. (Pres. L, 1907.) 16 Gloucester-terrace, Hyde Park, W.
1902. ‡Mahon, J. L. 2 May-street, Drumcondra, Dublin.
1907. *Mair, David. Civil Service Commission, Burlington-gardens, W.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1905. §Maltby, Lieutenant G. R., R.N. 54 St. George's-square, S.W.
1897. ‡Mance, Sir H. C. Old Woodbury, Sandy, Bedfordshire.
1903. ‡Manifold, C. C. 16 St. James's-square, S.W.
1905. ‡Manning, D. W., F.R.G.S. Roydon, Rosebank, Cape Town.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1905. ‡Mansfield, J. D. 94 St. George's-street, Cape Town.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1902. *Marchant, Dr. E. W. The University, Liverpool.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1900. ‡Margerison, Samuel. Calverley Lodge, near Leeds.
1864. ‡Markham, Sir Clements R., K.C.B., F.R.S., F.R.G.S., F.S.A. (Pres. E, 1879; Council, 1893–96.) 21 Eccleston-square, S.W.
1905. §Marks, Samuel. P.O. Box 379, Pretoria.
1905. ‡Marloth, R., M.A., Ph.D. P.O. Box 359, Cape Town.
1881. *Marr, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council, 1896–1902.) St. John's College, Cambridge.
1903. §Marriott, William. Royal Meteorological Society, 70 Victoria-street, S.W.
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry Carpenter. 3 Lower James-street, Golden-square, W.
1887. ‡Marsh, J. E., M.A., F.R.S. University Museum, Oxford.
1889. *Marshall, Alfred, M.A., LL.D., D.Sc. (Pres. F, 1890), Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1904. ‡Marshall, F. H. A. University of Edinburgh.
1905. §Marshall, G. A. K. 6 Chester-place, Hyde Park-square, W.
1892. §Marshall, Hugh, D.Sc., F.R.S., F.R.S.E. 12 Lonsdale-terrace, Edinburgh.
1901. ‡Marshall, Robert. 97 Wellington-street, Glasgow.
1886. *Marshall, William Bayley, M.Inst.C.E. 21 St. John's Wood-park, N.W.
1907. §Marston, Robert. 14 Ashleigh-road, Leicester.
1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1891. *Martin, Edward P., J.P. The Hill, Abergavenny, Monmouthshire.
1905. ‡Martin, John. P.O. Box 217, Germiston, Transvaal.
1884. §Martin, N. H., J.P., F.R.S.E., F.L.S. Ravenswood, Low Fell, Gateshead.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.

Year of Election.

1871. ‡MARWICK, Sir J. D., LL.D., F.R.S.E. (Local Sec. 1871, 1876, 1901.) Glasgow.
1905. ‡Marwick, J. S. P.O. Box 1166, Johannesburg.
1905. ‡Marx, Mrs. Charles. Shabana, Robinson-street, Belgravia, South Africa.
1907. §Masefield, J. R. B., M.A. Rosehill, Cheadle, Staffordshire.
1847. ‡MASKELYNE, NEVIL STORY, M.A., D.Sc., F.R.S., F.G.S. (Council, 1874–80). Basset Down House, Swindon.
1905. *Mason, Justice A. W. Supreme Court, Pretoria.
1893. *Mason, Thomas. Enderleigh, Alexandra-park, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1905. §Massy, Miss Mary. York House, Teignmouth, Devon.
1898. ‡*Masterman, A. T. University of St. Andrews, N.B.*
1901. *Mather, G. R. Boxlea, Wellingborough.
1887. *Mather, Sir William, M.Inst.C.E. Salford Iron Works, Man-chester.
1908. §Matheson, Sir R. E., LL.D. Charlemont House, Rutland-square, Dublin.
1905. ‡Mathew, Alfred Harfield. P.O. Box 242, Cape Town.
1894. ‡MATHEWS, G. B., M.A., F.R.S. St. John's College, Cambridge.
1902. ‡Matley, C. A., D.Sc. 7 Morningside-terrace, Edinburgh.
1904. ‡Matthews, D. J. The Laboratory, Citadel Hill, Plymouth.
1905. ‡Matthews, J. Wright, M.D. P.O. Box 437, Johannesburg.
1893. ‡Mavor, Professor James. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Sir Hiram S. Thurlow Park, Norwood-road, West Norwood, S.E.
1903. ‡Maxwell, J. M. 37 Ash-street, Southport.
1901. *May, W. Page, M.D., B.Sc. University College, Gower-street, W.C.
1884. *Maybury, A. C., D.Sc. 411 Fulham-road, S.W.
1905. §Maylard, A. Ernest. 10 Blythswood-square, Glasgow.
1905. ‡Maylard, Mrs. 10 Blythswood-square, Glasgow.
1878. *Mayne, Thomas. 19 Lord Edward-street, Dublin.
1904. ‡Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1905. ‡Mearns, J. Herbert, M.D. Edenville, 10 Oxford-road, Observatory, Cape Town.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1905. §Mein, W. W. P.O. Box 1024, Johannesburg.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C. (Pres. B, 1895; Council, 1892–99), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1883. ‡Mellis, Rev. James. 23 Part-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Cliff Hill, Warwick.
1896. §Mellor, G. H. Weston, Blundellsands, Liverpool.
1881. §Melrose, James. Clifton Croft, York.
1905. *Melvill, E. H. V., F.G.S., F.R.G.S. P.O. Box 719, Johannesburg.
1901. ‡*Mennell, F. P. 8 Addison-road, W.*
1905. §Meredith, H. O. Dunwood House, Withington, Manchester.
1908. §MEREDITH, Sir JAMES, LL.D. (Local Treas. 1908.) Royal University of Ireland, Dublin.
1879. ‡MERIVALE, JOHN HERMAN, M.A. (Local Sec. 1889.) Togston Hall, Acklington.
1899. *Merrett, William H., F.I.C. Hatherley, Grosvenor-road, Wallington, Surrey.
1905. ‡Merriman, Hon. John X. Schoongezicht, Stellenbosch, Cape Colony.

Year of Election.

1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1905. ‡Methven, Cathcart W. Club Arcade, Smith-street, Durban.
1896. §Metzler, W. H., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S. (Pres. D, 1897; Local Sec. 1890.) 1 Richmond-mount, Headingley, Leeds.
1903. ‡Micklethwait, Miss F. G. Queen's College, Galway.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Bishop's House, Middlesbrough.
1904. ‡Middleton, T. H., M.A. South House, Barton-road, Cambridge.
1894. *MIERS, H. A., M.A., F.R.S., F.G.S. (Pres. C, 1905), Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1885. §MILL, HUGH ROBERT, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W.
1905. §Mill, Mrs. H. R. 62 Camden-square, N.W.
1889. *MILLAR, ROBERT COCKBURN, 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1895. ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1902. ‡Millin, S. T. Sheridan Lodge, Helen's Bay, Co. Down.
1904. §Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1905. §Mills, Mrs. A. A. 36 St. Andrews-street, Cambridge.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1907. §Milne, A., M.A. University School, Hastings.
1882. *MILNE, JOHN, D.Sc., F.R.S., F.G.S. Shide, Newport, Isle of Wight.
1903. *Milne, R. M. Royal Naval College, Dartmouth, South Devon.
1898. *Milner, S. Roslington, D.Sc. The University, Sheffield.
1907. §Milton, J. H., F.G.S. Harrison House, Crosby, Liverpool.
1880. ‡MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Coopers Hill, Surrey.
1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1905. ‡Mitchell, John. Government School House, Jeppestown, Transvaal.
1885. ‡MITCHELL, P. CHALMERS, M.A., D.Sc., F.R.S., Sec.Z.S. (Council, 1906– .) 3 Hanover-square, W.
1905. *Mitchell, William Edward. Ferreira Deep, Johannesburg.
1908. §Mitchell, W. M. 2 St. Stephen's Green, Dublin.
1905. ‡Mitter, M. Care of J. Speak, Esq., The Grange, Kirton, near Boston.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1905. §Moir, James, D.Sc. Mines Department, Johannesburg.
1905. ‡Moir, Dr. W. Ironside. Care of Dr. McAulay, Cleveland, Transvaal.
1905. §Molengraaff, Professor G. A. F. The Technical University of Delft, The Hague.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1908. §Molloy, W. R. J., J.P., M.R.I.A. 78 Kenilworth-square, Rathgar, Co. Dublin.
1900. *MONCKTON, H. W., Treas.L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C.
1905. *MONCRIEFF, Colonel Sir C. SCOTT, G.C.S.I., K.C.M.G., R.E. (Pres. G, 1905.) 11 Cheyne-walk, S.W.
1905. ‡Moncrieff, Lady Scott. 11 Cheyne-walk, S.W.
1887. *MOND, LUDWIG, Ph.D., D.Sc., F.R.S., F.C.S. (Pres. B, 1896.) 20 Avenue-road, Regent's Park, N.W.

Year of Election.

1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1905. *Moore, Brian. Thornhill Villa, Marsh, Huddersfield.
1905. ‡*Moore, Charles Elliott. P.O. Box 5382, Johannesburg.*
1894. §Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1908. §Moore, Sir John W., M.D. 40 Fitzwilliam-square West, Dublin.
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1905. §Moore, T. H. Thornhill Villa, Marsh, Huddersfield.
1896. *Mordey, W. M. 82 Victoria-street, S.W.
1905. ‡More, T. E. Padern. Carlton Buildings, Parliament-street, Cape Town.
1901. *Moreno, Francisco P. Paraná 915, Buenos Aires.
1905. *Morgan, Miss Annie. Friedrichstrasse No. 2, Vienna.
1895. ‡Morgan, C. Lloyd, F.R.S., F.G.S., Principal of University College, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1896. ‡Morgan, George. 21 Upper Parliament-street, Liverpool.
1902. ‡Morgan, Gilbert T., D.Sc., F.I.C. Royal College of Science, S.W.
1902. *Morgan, Septimus Vaughan. 37 Harrington-gardens, S.W.
1901. *Morison, James. Perth.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 5 Lyndhurst-road, Hampstead, N.W.
1906. ‡Morrell, H. R. Scarcroft-road, York.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1905. ‡Morris, F., M.B., B.Sc. 18 Hope-street, Cape Town.
1896. *Morris, J. T. 13 Somers-place, W.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1907. §Morris, Colonel Sir W. G., K.C.M.G. Care of Messrs. Cox & Co., 16 Charing Cross, W.C.
1899. *Morrow, John, M.Sc., D.Eng. Armstrong College, Newcastle-upon-Tyne.
1865. ‡Mortimer, J. R. St. John's Villas, Driffield.
1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
1896. *Morton, William B., M.A., Professor of Natural Philosophy in Queen's College, Belfast.
1878. *Moss, John Francis, F.R.G.S. (Local Sec. 1879.) Edgebrook Cottage, Brincliffe, Sheffield.
1876. §Moss, Richard Jackson, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1892. *Mostyn, S. G., M.A., M.B. 1 Grange-avenue, Harton, near South Shields.
1866. ‡Mott, Frederick T., F.R.G.S. Crescent House, Leicester.
1878. *Moulton, The Right Hon. Lord Justice, M.A., K.C., F.R.S. 57 Onslow-square, S.W.
1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1905. §Moylan, Miss V. C. 3 Canning-place, Palace Gate, W.
1905. *Moysey, Miss E. L. Pitcroft, Guildford, Surrey.
1899. *Muff, Herbert B., B.A., F.G.S. Geological Survey Office, 33 George-square, Edinburgh.
1902. §Muir, Arthur H. 2 Wellington-place, Belfast.
1907. *Muir, Professor James. 189 Renfrew-street, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A. Gonville and Caius College, Cambridge.
1904. §Muir, William. Rowallan, Newton Stewart, N.B.
1872. *Muirhead, Alexander, D.Sc., F.R.S., F.C.S. 12 Carteret-street, Queen Anne's Gate, Westminster, S.W.

Year of Election.

1905. *Muirhead, James M. P., F.R.S.E. Markham's-chambers, St. George's-street, Cape Town.
1876. *Muirhead, Robert Franklin, M.A., D.Sc. 64 Great George-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1884. *Müller, Hugo, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1905. ‡Mulligan, A. 'Natal Mercury' Office, Durban, Natal.
1904. §Mullinger, J. Bass, M.A. 1 Bene't-place, Cambridge.
1898. ‡Mumford, C. E. Cross Roads House, Bouverie-road, Folkestone.
1901. *Munby, Alan E. Royal Societies Club, St. James's-street, S.W.
Munby, Arthur Joseph. 6 Fig Tree-court, Temple, E.C.
1906. ‡Munby, Frederick J. Whixley, York.
1904. ‡Munro, A. Queens' College, Cambridge.
1883. *Munro, Robert, M.A., M.D., LL.D. (Pres. H, 1893.) Elmbank, Largs, Ayrshire, N.B.
1890. ‡Murphy, A. J. Springfield Mount, Leeds.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1905. ‡Murray, Charles F. K., M.D. Kenilworth House, Kenilworth, Cape Colony.
1905. ‡Murray, Dr. F. Londinium, London-road, Sea Point, Cape Town.
1891. ‡Murray, G. R. M., F.R.S., F.R.S.E., F.L.S. 8 Kerrison-road, Ealing, W.
1905. §Murray, Dr. J. A. H. Sunnyside, Oxford.
1905. §Murray, Mrs. Sunnyside, Oxford.
1884. ‡Murray, Sir John, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., F.R.S.E. (Pres. E, 1899.) House of Falkland, Falkland, N.B.
1903. §Murray, Colonel J. D. Rowbottom-square, Wigan.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1902. ‡Myddleton, Alfred. 62 Duncairn-street, Belfast.
1902. *Myers, Charles S., M.A., M.D. Melrose, Grange-road, Cambridge.
1906. ‡Myers, Jesse A. Glengarth, Walker-road, Harrogate.
1890. *Myres, John L., M.A., F.S.A., Professor of Greek in the University of Liverpool. 1 Norham-gardens, Oxford.

1886. ‡Nagel, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1892. *Nairn, Sir Michael B., Bart. Kirkcaldy, N.B.
1890. ‡Nalder, Francis Henry. 34 Queen-street, E.C.
1905. ‡Napier, Dr. Francis. 73 Jeppe-street, Von Brandis-square, Johannesburg.
1872. ‡Nares, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
1898. *Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡Neville, F. H., M.A., F.R.S. Sidney College, Cambridge.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S. Madingley Rise, Cambridge.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.
1892. ‡Newton, E. T., F.R.S., F.G.S. Florence House, Willow Bridge-road, Canonbury, N.
1887. *Nicholson, John Carr, J.P. Moorfield House, Headingley, Leeds.

Year of Election.

1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1863. *NOBLE, Sir ANDREW, Bart., K.C.B., D.Sc., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890; Council, 1903–06; Local Sec. 1863). Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1908. §Norman, Conolly, M.D. St. Dymphna's, North Circular-road, Dublin.
1888. ‡Norman, George. 12 Brock-street, Bath.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution-hill, Ipswich.
1903. ‡Noton, John. 45 Part-street, Southport.
1908. §Nutting, Sir John, Bart. St. Helen's, Co. Dublin.

1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.
1883. ‡Odgers, William Blake, M.A., LL.D., K.C. 15 Old-square, Lincoln's Inn, W.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council, 1865–70), Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1908. §O'Farrell, Thomas A. 30 Lansdowne-road, Dublin.
1894. ‡Ogden, James. Kilner Deyne, Rochdale.
1902. ‡Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, C.B., M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W.
1905. *Oke, Alfred William, B.A., LL.M., F.G.S., F.L.S. 32 Denmark-villas, Hove, Brighton.
1905. §Okell, Samuel, F.R.A.S. Overley, Langham-road, Bowdon, Cheshire.
1892. ‡OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1893. *OLDHAM, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., 9 Pall Mall, S.W.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.R.S., F.L.S. (Pres. K, 1906), Professor of Botany in University College, London. 2 The Vale, Chelsea, S.W.
1883. ‡Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. ‡Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.L.S., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1908. §O'Neill, Rev. G., M.A. University College, St. Stephen's Green, Dublin.
1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.
1902. ‡O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1905. ‡O'Riley, J. C. 70 Barnet-street, Gardens, Cape Town.
1884. *Orpen, Rev. T. H., M.A. The Vicarage, Great Shelford, Cambridge.

Year of Election.

1901. §Orr, Alexander Stewart. Care of Messrs. Marsland, Price, & Co., Nesbit-road, Mazagon, Bombay, India.
1905. ‡Orr, Professor John. Transvaal Technical Institute, Johannesburg.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1905. ‡Osborn, Philip B. P.O. Box. 4181, Johannesburg.
1901. ‡Osborne, W. A., D.Sc. University College, W.C.
1887. ‡O'Shea, L. T., B.Sc. University College, Sheffield.
1865. *Osler, Henry F. Coppy-hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, WILLIAM, M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford. University Museum, Oxford.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1906. ‡Owen, Rev. E. C. St. Peter's School, York.
1903. *Owen, Edwin, M.A. Terra Nova School, Birkdale, Lancashire.
1889. **Owen, Alderman, H. C. Compton, Wolverhampton.*
1896. §Owen, Peter. The Elms, Capenhurst, Chester.

1906. §Page, Carl D. Wyoming House, Aylesbury, Bucks.
1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1870. *PALGRAVE, ROBERT HARRY INGLIS, F.R.S., F.S.S. (Pres. F, 1883.) Henstead Hall, Wrentham, Suffolk.
1896. ‡Pallis, Alexander. Tatoi, Argbarth-drive, Liverpool.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1904. ‡PARKER, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1905. ‡Parker, Hugh. P.O. Box 200, Pietermaritzburg, Natal.
1905. ‡Parker, John. 37 Hout-street, Cape Town.
1891. ‡PARKER, WILLIAM NEWTON, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1905. *Parkes, Tom E. P.O. Box 4580, Johannesburg.
1899. *Parkin, John. Blaithwaite, Carlisle.
1905. *Parkin, Thomas. Blaithwaite, Carlisle.
1906. §Parkin, Thomas, M.A., F.Z.S., F.R.G.S. Fairseat, High Wickham, Hastings.
1879. *Parkin, William. The Mount, Sheffield.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo, near Liverpool.
1908. §Parry, W. R., M.Inst.C.E. 6 Charlemont-terrace, Kingstown, Dublin.
1878. ‡PARSONS, Hon. C. A., C.B., M.A., Sc.D., F.R.S., M.Inst.C.E. (Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. ‡Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1905. *Parsons, Hon. Geoffrey L. Northern Counties Club, Newcastle-on-Tyne.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in the University of Liverpool.
1897. ‡Paton, D. Noël, M.D. Physiological Laboratory, The University, Glasgow.
1883. *Paton, Rev. Henry, M.A. 120 Polwarth-terrace, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 32 Harlow Moor-drive, Harrogate.

Year of Election.

1863. ‡PAVY, FREDERICK WILLIAM, M.D., LL.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Standard Iron Works, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1877. *Payne, J. C. Charles, J.P. Albion-place, The Plains, Belfast.
1881. ‡Payne, Mrs. Albion-place, The Plains, Belfast.
1888. *Paynter, J. B. Hendford Manor, Yeovil.
1876. ‡Peace, G. H., M.Inst.C.E. Monton Grange, Eccles, near Manchester.
1906. ‡Peace, Miss Gertrude. 39 Westbourne-road, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1886. *Pearce, Mrs. Horace. Collingwood, Manby-road, West Malvern.
1905. ‡Pearse, S. P.O. Box 149, Johannesburg.
1883. ‡Pearson, Arthur A., C.M.G. Hillsborough, Heath-road, Petersfield, Hampshire.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. §Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1905. §Pearson, Professor H. H. W., M.A., F.L.S. South African College, Cape Town.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.
1906. §Pearson, Joseph. The University, Liverpool.
1904. ‡Pearson, Karl, M.A., F.R.S., Professor of Applied Mathematics in University College, London, W.C.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *PECKOVER, Lord, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. Dorman's Park, near East Grinstead.
1901. *Peel, Hon. William. 13 King's Bench-walk, Temple, E.C.
1905. §Peirson, J. Waldie. P.O. Box 561, Johannesburg.
1905. §Pemberton, Gustavus M. P.O. Box 93, Johannesburg.
1887. ‡PENDLEBURY, WILLIAM H., M.A., F.C.S. (Local Sec. 1899.) Woodford House, Mountfields, Shrewsbury.
1894. ‡Pengelly, Miss. Lamorna, Torquay.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Pentecost, Rev. Harold, M.A. The School, Giggleswick, Yorkshire.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 1 Chesham-street, S.W.
1905. ‡Péringuey, L., D.Sc., F.Z.S. South African Museum, Cape Town.
1894. ‡PERKIN, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1902. *Perkin, F. Mollwo, Ph.D. The Firs, Hengrave-road, Honor Oak Park, S.E.
1884. ‡PERKIN, WILLIAM HENRY, LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council, 1901–07), Professor of Organic Chemistry in the Victoria University, Manchester. Fairview, Wilbraham-road, Fallowfield, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1874. *PERRY, JOHN, M.E., D.Sc., LL.D., F.R.S. (GENERAL TREASURER, 1904– ; Pres. G, 1902; Council, 1901–04), Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.

Year of Election.

1900. §Petavel, J. E., F.R.S. The University, Manchester.
1901. ‡Pethybridge, G. H. Royal College of Science, Dublin.
1895. ‡PETRIE, W. M. FLINDERS, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Hove, Brighton.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1903. ‡Philip, James C. 20 Westfield-terrace, Aberdeen.
1905. ‡Philip, John W. P.O. Box 215, Johannesburg.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1905. §Phillimore, Miss C. M. Shiplake House, Henley-on-Thames.
1899. *Phillips, Charles E. S. Castle House, Shooter's Hill, Kent.
1894. ‡Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1902. ‡Phillips, J. St. J., B.E. 64 Royal-avenue, Belfast.
1890. ‡Phillips, R. W., M.A., D.Sc., F.L.S., Professor of Botany in University College, Bangor. 2 Snowdon-villas, Bangor.
1905. ‡Phillp, Miss M. E. de R., B.Sc. 12 Crescent-grove, Clapham, S.W.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Isca, Merlin-road, Blackburn.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1907. §Pickles, A. R., M.A. Todmorden-road, Burnley.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1865. ‡PIKE, L. OWEN. 10 Chester-terrace, Regent's Park, N.W.
1896. *Pilkington, A. C. Rocklands, Rainhill, Lancashire.
1905. ‡Pilling, Arnold. Royal Observatory, Cape Town.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1905. ‡Pim, Miss Gertrude. Charleville, Blackrock, Co. Dublin.
1893. *PITT, WALTER, M.Inst.C.E. South Stoke House, near Bath.
1900. *Platts, Walter. Fairmount, Bingley.
1898. §Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1907. *Plunkett, Right Hon. Sir Horace, K.C.V.O., M.A., F.R.S. Kelteragh, Foxrock, Co. Dublin.
1900 *Pocklington, H. Cabourn, F.R.S. 11 Regent's Park-terrace, Leeds.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1904. §Pollard, William. 12 Aberdare-gardens, South Hampstead, N.W.
1896. *Pollex, Albert. Tenby House, Egerton Park, Rockferry.
1908. §Pollok, James H., D.Sc. 6 St. James's-terrace, Clonshea, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1906. *Pontifex, Miss Catherine E. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1907. §Pope, Alfred, J.P. South Court, Dorchester.
1900. *POPE, W. J., F.R.S., Professor of Chemistry in the Municipal School of Technology, Manchester. Corchester, Bramhall, Cheshire.
1907. *Poppleton, Mrs. A. G. 12 Hyde Park-gate, S.W.
1901. §Porter, Alfred W., B.Sc. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1905. §Porter, J. B., Ph.D., M.Inst.C.E., Professor of Mining Engineering in the McGill University, Montreal, Canada.

Year of Election.

1905. ‡Porter, Mrs. McGill University, Montreal, Canada.
1883. ‡POTTER, M. C., M.A., F.L.S., Professor of Botany in the Armstrong College, Newcastle-upon-Tyne. 13 Highbury, Newcastle-upon-Tyne.
1906. ‡Potter-Kirby, Alderman George. Clifton Lawn, York.
1907. §Potts, F. A. University Museum of Zoology, Cambridge.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council, 1895–1901, 1905–), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Mrs. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer, M.A. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Miss. Wykeham House, Banbury-road, Oxford.
1905. ‡Poulton, Miss M. Wykeham House, Banbury-road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1887. *Powell, Horatio Gibbs, F.R.G.S. Wood Villa, Tettenhall Wood, Wolverhampton.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1883. ‡POYNTING, J. H., D.Sc., F.R.S. (Pres. A, 1899), Professor of Physics in the University of Birmingham. 10 Ampton-road, Edgbaston, Birmingham.
1907. *PRAIN, Lieut.-Col. DAVID, C.I.E., M.B., F.R.S. (Council, 1907– .) Royal Gardens, Kew.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1906. §Pratt, Miss Edith M., D.Sc. The Woodlands, Silverdale, Lancashire.
1869. *PREECE, Sir WILLIAM HENRY, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1888; Council, 1888–95, 1896–1902.) Gothic Lodge, Wimbledon Common, S.W.
1888. *Preece, W. Llewellyn. Bryn Helen, Woodborough-road, Putney, S.W.
1904. §Prentice, Mrs. Manning. Thelema, Undercliff-road, Felixstowe.
1892. ‡Prentice, Thomas. Willow Park, Greenock.
1906. ‡Pressly, D. L. Coney-street, York.
1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1905. ‡Pretoria, The Right Rev. the Bishop of, D.D. Pretoria.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898–1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1897. *PRICE, W. A., M.A. Charlton, Headington, Oxford.
1905. ‡Prince, James Perrott, M.D. Durban, Natal.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1881. §Procter, John William. Ashcroft, York.
1884. *Proudfoot, Alexander, M.D. 100 State-street, Chicago, U.S.A.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1907. §Pryce, George Arthur. Care of Philip Harris & Co., Limited, 144 Edmund-street, Birmingham.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge

Year of Election.

1867. *Pullar, Sir Robert, M.P., F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1903. §Pullen-Burry, Miss. Care of Mrs. Kilvington, Coniston, Avondale-road, South Croydon.
1904. ‡Punnett, R. C. Caius College, Cambridge.
1905. ‡Purcell, W. F., M.A., Ph.D. South African Museum, Cape Town.
1905. ‡Purcell, Mrs. W. F. South African Museum, Cape Town.
1885. ‡PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines Castle, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., LL.D., M.R.I.A. (Pres. A, 1902.) Rathmines Castle, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1905. ‡Purvis, Mr. P.O. Box 744, Johannesburg.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. 27 Park-hill Rise, Croydon.
1883. ‡Pye-Smith, Mrs. 27 Park-hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1905. ‡Raine, Miss. P.O. Box 788, Johannesburg.
1905. ‡Raine, Robert. P.O. Box 1091, Johannesburg.
1898. *Raisin, Miss Catherine A., D.Sc., Bedford College, York-place, Baker-street, W.
1896. *RAMAGE, HUGH, M.A. The Technical Institute, Norwich.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1876. *RAMSAY, Sir WILLIAM, K.C.B., Ph.D., D.Sc., F.R.S. (Pres. B, 1897; Council, 1891–98), Professor of Chemistry in University College, London. 19 Chester-terrace, Regent's Park, N.W.
1883. ‡Ramsay, Lady. 19 Chester-terrace, Regent's Park, N.W.
1869. *Rance. H. W. Henniker, LL.D. 10 Castletown-road, W.
1907. §Rankine, A. O. 21 Drayton-road, West Ealing, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. ‡Rapkin, J. B. Thrale Hall, Streatham, S.W.
§Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1903. §Rastall, R. H. Christ's College, Cambridge.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. (Pres. E, 1891.) 2 York-mansions, Battersea Park, S.W.
1905. ‡Rawson, Colonel Herbert E., R.E. Army Headquarters, Pretoria.
1868. *RAYLEIGH, The Right Hon. Lord, O.M., M.A., D.C.L., LL.D., Pres.R.S., F.R.A.S., F.R.G.S. (PRESIDENT, 1884; TRUSTEE, 1883– ; Pres. A, 1882; Council, 1878–83), Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.

Year of Election.

1895. ‡Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree, M.A. Elm Lodge, Queen's-road, Teddington, Middlesex.
1907. §Rea, Carleton, B.C.L. 34 Fougate-street, Worcester.
1896. *READ, CHARLES H., F.S.A. (Pres. H, 1899.) British Museum, W.C.
1902. ‡Reade, R. H. Wilmount, Dunmurry.
1884. §Readman, J. B., D.Sc., F.R.S.E. Staffield Hall, Kirkoswald, R.S.O., Cumberland.
1852. *REDFERN, Professor PETER, M.D. (Pres. D, 1874.) 4 Lower-crescent, Belfast.
1890. *Redwood, Sir Boverton, F.R.S.E., F.C.S. Wadham Lodge, Wadham-gardens, N.W.
1908. §Reed, Sir Andrew, K.C.B., C.V.O., LL.D. 23 Fitzwilliam-square, Dublin.
1905. §Reed, J. Howard., F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunscar, Oaken, near Wolverhampton.
1891. *Rees, I. Treharne, M.Inst.C.E. Blaenypant, near Newport, Monmouthshire.
1903. §Reeves, E. A., F.R.G.S. 1 Savile-row, W.
1906. *Reichel, Sir H. R., LL.D., Principal of University College, Bangor. Penrallt, Bangor, North Wales.
1901. *Reid, Andrew T. 10 Woodside-terrace, Glasgow.
1904. §Reid, Arthur H. 30 Welbeck-street, W.
1881. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. 28 Jermyn-street, S.W.
1903. *Reid, Mrs. E. M., B.Sc. 7 St. James's-mansions, West End-lane, N.W.
1892. ‡REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1904. ‡Reid, P. J. Moor Cottage, Nunthorpe, R.S.O., Yorkshire.
1897. ‡Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1875. ‡REINOLD, A. W., M.A., F.R.S. (Council, 1890–95), Professor of Physics in the Royal Naval College, Greenwich, S.E.
1894. ‡Rendall, Rev. G. H., M.A., Litt.D. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. §RENDLE, Dr. A. B., M.A., F.L.S. 47 Wimbledon Park-road, Wimbledon.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1906. ‡Rennie, John, D.Sc. Natural History Department, University of Aberdeen.
1905. *Renton, James Hall. Rowfold Grange, Billinghurst, Sussex.
1905. ‡Reunert, Clive. Windybrow, Johannesburg.
1905. ‡Reunert, John. Windybrow, Johannesburg.
1904. §REUNERT, THEODORE, M.Inst.C.E. P.O. Box 92, Johannesburg.
1905. §Reyersbach, Louis. P.O. Box 149, Johannesburg.
1883. *Reynolds, A. H. 271 Lord-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., F.C.S M.R.I.A. (Pres. B, 1893; Council, 1893–99.) 29 Campd Hill-court, W.
1900. *Reynolds, Miss K. M. 8 Darnley-road, Notting Hill, W.

Year of Election.

1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1887.) 19 Lady Barn-road, Fallowfield, Manchester.
1906. ‡Reynolds, S. H., M.A., Professor of Geology and Zoology in University College, Bristol.
1907. §Reynolds, W. Birstall Holt, near Leicester.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1899. *RHYS, Professor Sir JOHN, D.Sc. (Pres. H, 1900.) Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro 14, Modena, Italy.
1905. §Rich, Miss Florence. Granville School, Granville-road, Leicester.
1906. ‡Richards, Rev. A. W. 12 Bootham-terrace, York.
1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh, M.A. 12 St. Mary's, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans. Trinity College, Cambridge.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. §Riches, T. Hurry. 8 Park-grove, Cardiff.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1902. §Ridgeway, William, M.A., Litt.D., Professor of Archæology in the University of Cambridge. Fen Ditton, Cambridge.
1894. ‡RIDLEY, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1881. *Rigg, Arthur. 150 Blomfield-crescent, W.
1883. *RIGG, EDWARD, I.S.O., M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
*RIPON, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, S.W.
1905. ‡Ritchie, Professor W., M.A. South African College, Cape Town.
1903. *Rivers, W. H. R., M.D. St. John's College, Cambridge.
1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
1902. *Roberts, Bruno. 30 St. George's-square, Regent's Park, N.W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, N.W.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. University of London, South Kensington, S.W.
1896. §Roberts, Thomas J. Ingleside, Park-road, Huyton, near Liverpool.
1904. *Robertson, Miss Agnes, D.Sc. 9 Elsworthy-terrace, Primrose Hill, N.W.
1897. §ROBERTSON, Sir GEORGE S., K.C.S.I. (Pres. E, 1900.) 1 Pump-court, Temple, E.C.
1905. ‡Robertson, Dr. G. W. Office of the Medical Officer of Health, Cape Town.
1897. §Robertson, Professor J. W., C.M.G., LL.D. The Macdonald College, St. Anne de Bellevue, Quebec, Canada.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. 154 West George-street, Glasgow.
1905. ‡Robertson, Professor T. E. Transvaal Technical Institute, Johannesburg.
1898. §Robinson, Charles E., M.Inst.C.E. Holne Cross, Ashburton, South Devon.
1903. ‡Robinson, G. H. 1 Weld-road, Southport.
1905. §Robinson, Harry. Duncan's-chambers, Shortmarket-street, Cape Town.

Year of Election.

1887. §Robinson, Henry, M.Inst.C.E. Parliament-mansions, Victoria-street, S.W.
1902. †Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1906. ‡Robinson, H. H., M.A., F.I.C. 75 Finborough-road, S.W.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.
1888. ‡Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1905. ‡Robinson, Dr. Leland. 6 Victoria-walk, Woodstock, Cape Town.
1899. *Robinson, Mark, M.Inst.C.E. 9 Belsize-grove, N.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1904. ‡Robinson, Theodore R. 25 Campden Hill-gardens, W.
1904. §Robinson, W. H. Kendrick House, Victoria-road, Penarth.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1906. §Robson, J. Nalton. The Villa, Hull-road, York.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, 6 Robert-street, Adelphi, W.C.
1905. ‡Roebuck, William Denison. 259 Hyde Park-road, Leeds.
1907. §Roechling, H. Alfred, M.Inst.C.E. 33 Highfield-street, Leicester.
1905. §Rogers, A. W., M.A., F.G.S. South African Museum, Cape Town.
1898. ‡Rogers, Bertram, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
1907. §Rogers, John D. 85 St. George's-square, S.W.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 15 Regent Park-avenue, Leeds.
1906. §Rogers, Reginald A. P. 142 Leinster-road, Dublin.
1884. *Rogers, Walter. Lamorva, Falmouth.
1876. ‡Rollit, Sir A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. 45 Belgrave-square, S.W.
1905. ‡Rooth, Edward. Pretoria.
1855. *Roscoe, Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., F.R.S. (President, 1887; Pres. B, 1870, 1884; Council, 1874–81; Local Sec. 1861.) 10 Bramham-gardens, S.W.
1905. ‡Rose, Miss G. 45 De Pary's-avenue, Bedford.
1905. ‡Rose, Miss G. Mabel. Ashley Lodge, Oxford.
1883. *Rose, J. Holland, Litt.D. Ethandune, Parkside-gardens, Wimbledon, S.W.
1905. ‡Rose, John G. Government Analytical Laboratory, Cape Town.
1894. *Rose, T. K., D.Sc., Chemist and Assayer to the Royal Mint. 6 Royal Mint, E.
1905. *Rosedale, Rev. H. G., D.D., F.S.A. St. Peter's Vicarage, 13 Ladbroke-gardens, W.
1905. *Rosedale, Rev. W. E., M.A. Willenhall, Staffordshire.
1905. ‡Rosen, Jacob. 1 Hopkins-street, Yeoville, Transvaal.
1905. ‡Rosen, Julius. Clifton Grange, Jarvie-street, Jeppestown, Transvaal.
1900. ‡Rosenhain, Walter, B.A. 443 Gillott-road, Edgbaston, Birmingham.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1908. §Ross, Sir John, of Bladensburg, K.C.B. Rostrevor House, Rostrevor, Co. Down.
1902. ‡Ross, John Callender. 46 Holland-street, Campden-hill, W.
1901. ‡Ross, Colonel Ronald, C.B., F.R.S., Professor of Tropical Medicine and Parasitology in the University of Liverpool. 36 Bentley-road, Liverpool.

Year of Election.

1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. *Roth, H. Ling. Briarfield, Shibden, Halifax, Yorkshire.
1865. *Rothera, George Bell. Hazlewood, Forest-grove, Nottingham.
1905. ‡Rothkugel, R. Care of Messrs. D. Isaacs & Co., Cape Town.
1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1884. *Rouse, M. L. Hollybank, Hayne-road, Beckenham.
1905. §Rousselet, Charles F. 2 Pembridge-crescent, Bayswater, W.
1883. ‡Rowan, Frederick John. 5 West Regent-street, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. 2 Price's-avenue, Margate.
1890. ‡Rowley, Walter, M.Inst.C.E., F.S.A. Alderhill, Meanwood, Leeds.
1906. §Rowntree, B. Seebohm. The Homestead. Clifton. York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1875. *RÜCKER, Sir A. W., M.A., D.Sc., F.R.S., Principal of the University of London (PRESIDENT, 1901 ; TRUSTEE, 1898- ; GENERAL TREASURER, 1891-98 ; Pres. A, 1894 ; Council, 1888-91). 19 Gledhow-gardens, South Kensington, S.W.
1869. §RUDLER, F. W., I.S.O., F.G.S. 18 St. George's-road, Kilburn, N.W.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. 26 Weston-park, Crouch End, N.
1905. *Ruffer, Marc Armand, C.M.G., M.A., M.D., B.Sc. Quarantine International Board, Alexandria.
1905. §Ruffer, Mrs. Alexandria.
1904. ‡Ruhemann, Dr. S. 3 Selwyn-gardens, Cambridge.
1896. *Rundell, T. W., F.R.Met.Soc. 25 Castle-street, Liverpool.
1904. ‡Russell, E. J., D.Sc., Rothamsted Experimental Station, Harpenden, Herts.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
Russell, John. 39 Mountjoy-square, Dublin.
1883. *Russell, J. W. 28 Staverton-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., V.P.C.S. (Pres B, 1873 ; Council, 1873-80.) 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1907. §Rutherford, Ernest, M.A., D.Sc., F.R.S., Professor of Physics in the University of Manchester.
1905. ‡Ryan, Pierce. Rosebank House, Rosebank, Cape Town.
1898. §Ryland, C. J. Southerndown House, Clifton, Bristol.
1906. *RYMER, Sir JOSEPH SYKES. The Mount, York.

1903. ‡SADLER, M. E., LL.D. (Pres. L, 1906), Professor of Education in the Victoria University, Manchester. Eastwood, Weybridge.
1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Church House, Westminster, S.W.
1903. ‡Sagar, J. The Poplars, Savile Park, Halifax.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1904. §SALTER, A. E., D.Sc., F.G.S. 20 Shell-road, Loampit Hill, Lewisham, S.E.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1901. ‡Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1907. *Sand, Dr. Henry J. S. University College, Nottingham.
1907. §Sandars, Miss Cora B. Parkholme, Elm Park-gardens, S.W.

Year of Election.

1883. ‡Sanderson, Lady Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. ‡Sang, William D. Tylehurst, Kirkcaldy, Fife.
1903. ‡Sankey, Captain H. R., R.E. Bawmore, Bilton, Rugby.
1886. ‡Sankey, Percy E. 44 Russell-square, W.C.
1905. ‡Sargant, E. B. Quarry Hill, Reigate.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1905. ‡Sargent, Miss Helen A., B.A. Huguenot College, Wellington, Cape Colony.
1907. §Sargent, H. C. Ambergate, near Derby.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1900. *SAUNDER, S. A. Fir Holt, Crowthorne, Berks.
1903. *Saunders, Miss E. R. Newnham College, Cambridge.
1901. ‡Sawers, W. D. 1 Athole Gardens-place, Glasgow.
1887. §SAYCE, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1906. §Sayer, Dr. Ettie. 35 Upper Brook-street, W.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1903. §SCARISBRICK, Sir CHARLES, J.P. Scarisbrick Lodge, Southport.
1903. ‡Scarisbrick, Lady. Scarisbrick Lodge, Southport.
1879. *SCHÄFER, E. A., LL.D., D.Sc., F.R.S., M.R.C.S. (GEN. SEC. 1895–1900; Pres. I, 1894; Council, 1887–93), Professor of Physiology in the University of Edinburgh.
1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1905. ‡*Scholer, W. Peter. Transvaal Technical Institute, Johannesburg.*
1885. ‡Scholes, L. Ivy Cottage, Parade, Parkgate, Cheshire.
1905. ‡Schonland, S., Ph.D. Albany Museum, Grahamstown, Cape Colony.
1908. §Schrädter, Dr. E. 3–5 Jacobistrasse, Düsseldorf, Germany.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S. (Pres. A, 1892; Council, 1887–93). Kent House, Victoria Park, Manchester.
1905. ‡Sclander, J. E. P.O. Box 465, Cape Town.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S. (GENERAL SECRETARY, 1876–81; Pres. D, 1875; Council, 1864–67, 1872–75.) Odiham Priory, Winchfield.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. South African Museum, Cape Town.
1905. ‡Sclater, Mrs. W. L. Crossroads, Baker-road, Wynberg, Cape Colony.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S., F.C.S. Royal Institution, Albemarle-street, W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., F.L.S. (GENERAL SECRETARY, 1900–03; Pres. K, 1896.) East Oakley House, Oakley, Hants.
1857. *SCOTT, ROBERT H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1902. ‡Scott, William R. The University, St. Andrews, Scotland.
1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.

Year of Election.

1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. St. Edmund's, 10 Worsley-road, Hampstead, N.W.
1890. *Searle, G. F. C., M.A., F.R.S. Wyncote, Hills-road, Cambridge.
1880. ‡Sedgwick, Adam, M.A., F.R.S. (Pres. D, 1899), Professor of Zoology and Comparative Anatomy in the University of Cambridge. 4 Cranmer-road, Cambridge.
1905. ‡Sedgwick, C. F. Strand-street, Cape Town.
1906. *See, T. J. J., A.M., Ph.D., Professor of Mathematics, U.S. Navy, in charge of the Naval Observatory, Mare Island, California.
1861. *Seeley, Harry Govier, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 3 Holland Park-court, Holland Park-gardens, W.
1904. ‡Sell, W. J. 19 Lensfield-road, Cambridge.
1904. ‡Sella, Professor Alfonso. Instituto Fisico, Rome.
1907. §Seligman, Dr. C. G. 15 York-terrace, Regent's Park, N.W.
1888. *Senier, Alfred, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1888. *Sennett, Alfred R., A.M.Inst.C.E. 15 Heath-mansions, Hampstead, N.W.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1905. ‡Serrurier, Louis C. Ashley, Sea Point, Cape Town.
1901. ‡Service, Robert. Janefield Park, Maxwelltown, Dumfries.
1895. *Seton-Karr, H. W. 31 Lingfield-road, Wimbledon, Surrey.
1892. *Seward, A. C., M.A., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901-07; Local Sec. 1904), Professor of Botany in the University of Cambridge. Westfield, Huntingdon-road, Cambridge.
1904. ‡Sewell, R. B. Seymour. Christ's College, Cambridge.
1899. §Seymour, Henry J., B.A., F.G.S. St. Peter's, Ailesbury-road, Dublin.
1891. ‡Shackell, F. W. 191 Newport-road, Cardiff.
1905. *Shackleford, W. C., M.Inst.M.E. County Club, Lancaster.
1904. ‡Shackleton, Ernest H., F.R.G.S. 14 South Learmonth-gardens, Edinburgh.
1902. ‡Shaftesbury, The Right Hon. the Earl of, D.L. Belfast Castle, Belfast.
1901. *Shakespear, Mrs. G. A. 21 Woodland-road, Northfield, Worcestershire.
1906. ‡Shann, Frederick. 6 St. Leonard's, York.
1878. ‡Sharp, David, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1904. ‡Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1889. *Shaw, Mrs. M. S., B.Sc. Sydenham Damarel Rectory, Tavistock.
1883. *Shaw, W. N., M.A., D.Sc., F.R.S. (Council, 1895-1900, 1904-07.) Meteorological Office, 63 Victoria-street, S.W.
1883. ‡Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
1904. ‡Shaw-Phillips, Miss. 19 Camden-crescent, Bath.
1903. ‡Shaw-Phillips, T., J.P. 19 Camden-crescent, Bath.
1905. ‡Shenstone, Miss A. Sutton Hall, Barcombe, Lewes.
1905. ‡Shenstone, Mrs. A. E. G. Sutton Hall, Barcombe, Lewes.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡Shenstone, W. A., F.R.S. Clifton College, Bristol.
1900. §Sheppard, Thomas, F.G.S. The Municipal Museum, Hull.
1905. ‡Sheridan, Dr. Norman. 96 Francis-street, Bellevue, Johannesburg.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.

Year of Election.

1896. §SHERRINGTON, C. S., M.D., F.R.S. (Pres. I, 1904; Council, 1907-), Professor of Physiology in the University of Liverpool. 16 Grove-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath.
1902. *Shillington, T. Foulkes, J.P. Dromart, Antrim-road, Belfast.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.
1887. *SHIPLEY, ARTHUR E., M.A., F.R.S. (Council, 1904- .) Christ's College, Cambridge.
1870. *SHOOLBRED, J. N., B.A., M.Inst.C.E. 47 Victoria-street, S.W.
1897. ‡SHORE, Dr. LEWIS E. St. John's College, Cambridge.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. 6 Kingswood-road, Upper Norwood, S.E.
1901. ‡Short, Peter M., B.Sc. 1 Holmdene-avenue, Herne Hill, S.E.
1904. *Shrubsall, F. C., M.A., M.D. Brompton Hospital, S.W.
1889. ‡Sibley, Walter K., M.A., M.D. The Mansions, 70 Duke-street, W.
1902. ‡Siddons, A. W. Harrow-on-the-Hill, Middlesex.
1883. *Sidebothan, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *SIEMENS, ALEXANDER, M.Inst.C.E. 12 Queen Anne's-gate, S.W.
1905. ‡Siemens, Mrs. A. 12 Queen Anne's-gate, S.W.
1903. *Silberrad, Dr. Oswald. Buckhurst Hill, Essex.
1871. *SIMPSON, Sir ALEXANDER R., M.D., Emeritus Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1901. *Simpson, Professor J. Y., M.A., D.Sc., F.R.S.E. 52 Queen-street, Edinburgh.
1907. §Simpson, Lieut.-Colonel R. J. S., C.M.G. 1 Amherst-avenue, Ealing, W.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
1896. *Simpson, W., F.G.S. Catteral Hall, Settle, Yorkshire.
1874. ‡SINCLAIR, Right Hon. THOMAS (Local Sec. 1874). Dunedin, Belfast.
1907. *Sircar, Dr. Amrita Lal, L.M.S., F.C.S. 51 Sankaritola, Calcutta.
1905. *SJOGREN, Professor H. Natural History Museum, Stockholm, Sweden.
1902. ‡Skeffington, J. B., M.A., LL.D. Waterford.
1906. ‡Skerry, H. A. St. Paul's-square, York.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1898. ‡SKINNER, SIDNEY, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1905. §Skyrme, C. G. 28 Norman-road, St. Leonard's-on-Sea.
1905. ‡Slater, Dr. H. B. 75 Bree-street, Johannesburg.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1887. ‡Small, Evan W., M.A., B.Sc., F.G.S. 48 Kedleston-road, Derby.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1903. *Smallman, Raleigh S. Wressil Lodge, Wimbledon Common, S.W.
1904. ‡Smart, Edward. Benview, Craigie, Perth, N.B.
1889. *SMART, Professor WILLIAM, LL.D. (Pres. F, 1904.) Nunholme, Dowanhill, Glasgow.
1902. §Smedley, Miss Ida. 11 Mecklenburgh-square, W.C.
1905. ‡Smith, Miss Adelaide. Huguenot College, Wellington, Cape Colony.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Chicago, Illinois, U.S.A.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.

Year of Election.

1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1873. ‡Smith, C. Sidney College, Cambridge.
1905. ‡Smith, C. H. Fletcher's-chambers, Cape Town.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Kodaikanal, South India.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897. ‡Smith, G. Elliot, M.D., F.R.S. St. John's College, Cambridge.
1903. *Smith, H. B. Lees. 16 Park-terrace, Oxford.
1889. *Smith, H. Llewellyn, C.B., B.A., B.Sc., F.S.S. Board of Trade, S.W.
1860. *Smith, Heywood, M.A., M.D. 25 Welbeck-street, Cavendish-square, W.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., Professor of Pathology in the Victoria University, Manchester.
1903. *Smith, James. Pinewood, Crathes, Aberdeen.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., Shirley, Station-road, Sidcup, Kent.
1896. *Smith, Rev. W. Hodson. Newquay, Cornwall.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
1883. ‡Smithells, Arthur, B.Sc., F.R.S. (Pres. B, 1907; Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1906. §Smurthwaite, Thomas E. 134 Mortimer-road, Kensal Rise, W.
1905. §Smuts, C. P.O. Box 1088, Johannesburg.
1908. §Smyly, Sir William J. 58 Merrion-square, Dublin.
1857. *Smyth, John, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *Snape, H. Lloyd, D.Sc., Ph.D. Balholm, Lathom-road, Southport.
1905. §Soddy, F. The University, Glasgow.
1905. §Sollas, Miss I. B. J., B.Sc. Newnham College, Cambridge.
1879. *Sollas, W. J., M.A., Sc.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900; Council, 1900–03), Professor of Geology in the University of Oxford. 173 Woodstock-road, Oxford.
1905. ‡Solomon, R. Stuart. Care of Messrs. R. M. Moss & Co., Cape Town.
1892. *Somervail, Alexander. The Museum, Torquay.
1900. *Somerville, W., D.Sc., F.L.S., Sibthorpian Professor of Rural Economy in the University of Oxford. 121 Banbury-road, Oxford.
1859. *Sorby, H. Clifton, LL.D., F.R.S., F.G.S. (Pres. C, 1880; Council, 1879–86; Local Sec. 1879.) Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1901. ‡Sorley, Robert. The Firs, Partickhill, Glasgow.
1903. ‡Soulby, R. M. Sea Holm, Westbourne-road, Birkdale, Lancashire.
1903. ‡Southall, Henry T. The Graig, Ross, Herefordshire.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.

Year of Election.

1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1905. ‡Spencer, Charles Hugh. P.O. Box 2, Maraisburg, Transvaal.
1889. *Spencer, John W. Impney Hall, Droitwich, Worcester.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen-park, Highbury, N.
1894. ‡Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 91 Savoy-court, Strand, W.C.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1905. ‡Squire, Mrs. Clarendon House, 30 St. John's Wood-park, N.W.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.C.
1903. ‡Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.
1883. *Stanford, Edward, F.R.G.S. 12–14 Long-acre, W.C.
1905. ‡Stanley, Professor George H. Transvaal Technical Institute, Johannesburg.
1881. *Stanley, William Ford, J.P., F.G.S. Cumberlow, South Norwood, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. McGill University, Montreal, Canada.
1900. *Stansfield, H., B.Sc. 20 Every-street, Ancoats, Manchester.
1905. ‡*Stanwell, H. B. South African College School, Cape Town.*
1905. ‡Stanwell, Dr. St. John. P.O. Box 1050, Johannesburg.
1905. ‡Stapleton, Frederick. Control and Audit Office, Cape Town.
1905. *Starkey, A. H. 24 Greenhead-road, Huddersfield.
1899. ‡STARLING, E. H., M.D., F.R.S., Professor of Physiology in University College, London, W.C.
1899. §Statham, William. The Redings, Totteridge, Herts.
1898. ‡Stather, J. W., F.G.S. Brookside, Newland Park, Hull.
Staveley, T. K. Ripon, Yorkshire.
1907. §Staynes, Frank. 36–38 Silver-street, Leicester.
1900. *Stead, J. E., F.R.S. Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Beech-road, Reigate.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 8 Playfair-mansions, Queen's Club-gardens, W.
1905. ‡Stebbins, Miss Inez F., B.A. Huguenot College, Wellington, Cape Town.
1905. ‡Stephen, J. M. Invernegie, Sea Point, Cape Colony.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1902. ‡Stephenson, G. Cuilin, Glasnevin, Dublin.
1906. §Stevens, Miss C. O. The Red House, Bradfield, Reading.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
1900. ‡STEVENS, FREDERICK (Local Sec. 1900). Town Clerk's Office, Bradford.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Murtle, Aberdeen.
1905. §Stewart, A. F. 127 Isabella-street, Toronto, Canada.
1905. ‡Stewart, Charles. Meteorological Commission, Cape Town.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1901. *Stewart, John Joseph, M.A., B.Sc. 35 Stow Park-avenue, Newport, Monmouthshire.
1901. *Stewart, Thomas. St. George's-chambers, Cape Town.

Year of Election.

1905. ‡Steyn, Dr. G. H. Kandahar, Salt River, Cape Colony.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Victoria University, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1904. §Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.
1906. *Stobo, Mrs. Annie. Somerset House, Garelochhead, Dumbartonshire, N.B.
1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
1898. *Stokes, Professor George J., M.A. 5 Fernhurst-villas, College-road, Cork.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1905. ‡Stoneman, Miss Bertha, D.Sc. Huguenot College, Wellington, Cape Colony.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1895. *Stoney, Miss Edith A. 30 Ledbury-road, Bayswater, W.
1878. *Stoney, G. Gerald. Oakley, Heaton-road, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. (Pres.A, 1897.) 30 Ledbury-road, Bayswater, W.
1903. *Stopes, Miss Marie, Ph.D., B.Sc. 53 Stanley-gardens, Haverstock Hill, N.W.
1883. ‡Stopes, Mrs. 53 Stanley-gardens, Haverstock Hill, N.W.
1887. *Storey, H. L. Bailrigg, Lancaster.
1884. ‡Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. Woolley Grange, Bradford-on-Avon, Wilts.
1905. *Stott, Clement H., F.G.S. P.O. Box 7, Pietermaritzburg, Natal.
1905. §Stower, Miss Alice. 34 Palace Gardens-terrace, W.
1871. *STRACHEY, Lieut.-General Sir RICHARD, R.E., G.C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. (Pres. E, 1875; Council, 1871–75.) 69 Lancaster-gate, Hyde Park, W.
1881. ‡STRAHAN, AUBREY, M.A., F.R.S., F.G.S. (Pres. C, 1904.) Geological Museum, Jermyn-street, S.W.
1905. §Strange, Harold F. P.O. Box 2527, Johannesburg.
1881. §STRANGWAYS, C. FOX, F.G.S. Kylemore, Hollycroft-avenue, West Hampstead, N.W.
1906. *Stromeyer, C. E. 9 Mount-street, Albert-square, Manchester.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M., M.D. 3 Champion-park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the Armstrong College, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the University of Leeds.
1905. ‡Struben, Mrs. A. P.O. Box 1228, Pretoria.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. 5 Prince's-square, W.
1885. ‡Stump, Edward C. Malmesbury, Polefield, Blackley, Manchester.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1891. *Sudborough, Professor J. J., Ph.D., D.Sc. University College of Wales, Aberystwyth.
1902. §Sully, H. T. Scottish Widows'-buildings, Bristol.
1898. §Sully, T. N. Avalon House, Queen's-road, Weston-super-Mare.

Year of Election.

1905. ‡Summer, A. B. Ollersett Booyseux, Transvaal.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1903. ‡Swallow, Rev. R. D., M.A. Chigwell School, Essex.
1905. ‡Swan, Miss Hilda. 58 Holland Park, W.
1881. §SWAN, Sir JOSEPH WILSON, M.A., D.Sc., F.R.S. 58 Holland Park, W.
1905. ‡Swan, Miss Mary E. 58 Holland-park, W.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1908. §Swanzy, Sir Henry R., M.D. 23 Merrion-square, Dublin.
1882. *Swaythling, Lord. 12 Kensington Palace-gardens, W.
1887. §SWINBURNE, JAMES, F.R.S., M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1887. *Swindells, Rupert, F.R.G.S. 22 Oxford-road, Birkdale, Southport.
1895. ‡Sykes, E. R., B.A. 3 Gray's Inn-place, W.C.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1887. *Sykes, George, H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1906. *Sykes, Miss M. G. Girton College, Cambridge.
1896. *Sykes, Mark L., F.R.M.S. 10 Headingley-avenue, Leeds.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.
1906. ‡Sykes, T. P., M.A. 4 Gathorne-street, Great Horton, Bradford.
1905. ‡Symington, C., M.B. Railway Medical Office, De Aar, Cape Colony.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885 ‡SYMINGTON, JOHNSON, M.D., F.R.S., F.R.S.E. (Pres. H, 1903), Professor of Anatomy in Queen's College, Belfast.
1905. ‡Symmes, H. C. P.O. Box 3902, Johannesburg.

1896. ‡Tabor, J. M. Holmwood, Haringey Park, Crouch End, N.
1904. §Tallack, H. T. Clovelly, Birdhurst-road, South Croydon.
1903. *Tanner, Miss Ellen G. 48 Campden House-court, Gloucester-walk, W.
1890. ‡TANNER, H. W. LLOYD, D.Sc., F.R.S. (Local Sec. 1891), Professor of Mathematics and Astronomy in University College, Cardiff.
1892. *Tansley, Arthur G., M.A., F.L.S. Grantchester, near Cambridge.
1883. *Tapscott, R. Lethbridge, F.R.A.S. 62 Croxteth-road, Liverpool.
1908. §Tarleton, Francis A., LL.D. 24 Upper Leeson-street, Dublin.
1861. *Tarratt, Henry W. 332 Marylebone-road, N.W.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1901. ‡Taylor, Benson. 22 Hayburn-crescent, Partick, Glasgow.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. ‡Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1906. ‡Taylor, H. Dennis. Stancliffe, Mount-villas, York.
1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1860. *Taylor, John, M.Inst.C.E., F.G.S. 6 Queen Street-place, E.C.
1906. §Taylor, Miss M. R. Newstead, Blundellsands.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1895. ‡Taylor, W. A., M.A., F.R.S.E. 3 East Mayfield, Edinburgh.
1894. *Taylor, W. W., M.A. 66 St. John's-road, Oxford.
1901. §Taylor, William. 57 Sparkenhoe-street, Leicester.
1903. ‡Taylor, William. 61 Cambridge-road, Southport.
1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.

Year of Election.

1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, J. J. H., M.A., F.R.S., F.G.S. (Pres. C, 1893; Council, 1894–1900), Director of the Geological Survey of the United Kingdom. The Museum, Jermyn-street, S.W.
1906. *Teape, Rev. W. M., M.A. South Hylton Vicarage, Sunderland.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. Solheim, Cumberland Park, Acton, W.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *Thane, George Dancer, LL.D., Professor of Anatomy in University College, London, W.C.
1871. ‡Thiselton-Dyer, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. (Pres. D, 1888; Pres. K, 1895; Council, 1885–89, 1895–1900.) The Ferns, Witcombe, Gloucester.
1906. §Thoday, D. Trinity College, Cambridge.
1870. ‡Thom, Colonel Robert Wilson, J.P. Brooklands, Lord-street West, Southport.
1891. *Thomas, Miss Clara. Pencerrig, Builth.
1903. ‡Thomas, Miss Ethel N. 3 Downe-mansions, Gondar-gardens, West Hampstead, N.W.
1880. *Thomas, Joseph William, F.C.S. Overdale, Shortlands, Kent.
1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
1902. *Thomas, Miss M. Beatrice. Girton College, Cambridge.
1904. ‡Thomas, Northcote W. 7 Coptic-street, W.C.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1904. *Thomas, William. Bryn-heulog, Merthyr Tydfil.
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
1888. *Thompson, Claude M., M.A., D.Sc., Professor of Chemistry in University College, Cardiff. 38 Park-place, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., C.B., Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1907. *Thompson, Edwin, 1 Croxteth-grove, Liverpool.
1883. *Thompson, Francis. Eversley, Haling Park-road, Croydon.
1904. *Thompson, G. R., B.Sc., Professor of Mining in the University of Leeds.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of National Bank of India, 17 Bishopsgate-street Within, E.C.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1905. ‡Thompson, James. P.O. Box 312, Johannesburg.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Cheshire.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1876. ‡Thompson, Silvanus Phillips, B.A., D.Sc., F.R.S., F.R.A.S. (Pres. G, 1907; Council, 1897–99), Principal and Professor of Physics in the City and Guilds of London Technical College, Leonard-street, Finsbury, E.C.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Chehires.
1896. *Thompson, W. H., M.D., D.Sc. (Local Sec. 1908), King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1905. ‡Thompson, William. Parkside, Doncaster-road, Rotherham.

Year of Election.

1894. ‡Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1906. §Thomson, F. Ross, F.G.S. Hensill, Hawkhurst, Kent.
1890. *Thomson, Professor J. Arthur, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡Thomson, J. J., M.A., D.Sc., F.R.S. (Pres. A, 1896; Council 1893–95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1901. ‡Thomson, Dr. J. T. Kilpatrick. 148 Norfolk-street, Glasgow.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1891. ‡Thomson, John. Westover, Mount Ephraim-road, Streatham, S.W.
1871. *Thomson, John Millar, LL.D., F.R.S. (Council, 1895–1901), Professor of Chemistry in King's College, London. 9 Campden Hill-gardens, W.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1905. *Thorneley, Miss L. R. Nunclose, Grassendale, Liverpool.
1906. §Thornely, Miss A. M. M. Oaklands, Bowdon, Cheshire.
1898. *Thornton, W. M., D.Sc., Professor of Electrical Engineering in the Armstrong College, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1903. ‡Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. 37 Pleasant-street, New Brighton, Cheshire.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. ‡Thorpe, Jocelyn Field, Ph.D. Owens College, Manchester.
1871. ‡Thorpe, T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1890; Council, 1886–92), Principal of the Government Laboratories, Clement's Inn-passage, W.C.
1883. §Threlfall, Henry Singleton, J.P. 1 London-street, Southport.
1899. §Threlfall, Richard, M.A., F.R.S. 30 George-road, Edgbaston, Birmingham.
1896. §Thrift, William Edward, M.A. (Local Sec. 1908), Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1904. §Thurston, Edgar. Government Museum, Madras.
1907. §Thwaites, R. E. 138 Kimberley-road, Leicester.
1889. ‡Thys, Colonel Albert. 9 Rue Briderode, Brussels.
1873. *Tiddeman, R. H., M.A., F.G.S. 175 Banbury-road, Oxford.
1905. ‡Tietz, Heinrich, B.A., Ph.D. South African College, Cape Town.
1874. ‡Tilden, William A., D.Sc., F.R.S., F.C.S. (Pres. B, 1888; Council, 1898–1904), Professor of Chemistry in the Royal College of Science, London. The Oaks, Northwood, Middlesex.
1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Liverpool.
1899. ‡Tims, H. W. Marett, M.A., M.D., F.L.S. Deepdene, Cavendish-avenue, Cambridge.
1902. §Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1905. ‡Tippett, A. M., M.Inst.C.E. Cape Government Railways, Cape Town.
1900. §Tocher, J. F., F.I.C. 5 Chapel-street, Peterhead, N.B.
1907. §Todd, Professor J. L. McGill University, Montreal.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1905. ‡Tonkin, Samuel. Rosebank, near Cape Town.

Year of Election.

1875. ‡Torr, Charles Hawley. 35 Burlington-road, Sherwood, Nottingham.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
1901. ‡Townsend, J. S. E., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1876. *Trail, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.
1883. ‡Traill, A., M.D., LL.D., Provost of Trinity College, Dublin, Ballylough, Bushmills, Ireland.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1868. ‡Traquair, Ramsay H., M.D., LL.D., F.R.S., F.G.S. (Pres. D, 1900.) The Bush, Colinton, Midlothian.
1902. ‡Travers, Ernest J. Dunmurry, Co. Antrim.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1905. §Trevor-Battye, A., M.A., F.L.S., F.R.G.S. Chilbolton, Stockbridge, R.S.O.
1871. ‡Trimen, Roland, M.A., F.R.S., F.L.S., F.Z.S. Ovingdean, King Charles-road, Surbiton Hill.
1902. §Tristram, Rev. J. F., M.A., B.Sc. 20 Chandos-road, Chorlton-cum-Hardy, Manchester.
1884. *Trotter, Alexander Pelham. 8 Richmond-terrace, Whitehall, S.W.
1887. *Trouton, Frederick T., M.A., Sc.D., F.R.S., Professor of Physics in University College, W.C.
1898. §Trow, Albert Howard, D.Sc., F.L.S., Professor of Botany in University College, Cardiff. 50 Clive-road. Penarth.
1885. *Tubby, A. H., F.R.C.S. 68 Harley-street, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1905. §Turmeau, Charles. Claremont, Victoria Park, Wavertree, Liverpool.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1893. ‡Turner, Dawson, M.B. 37 George-square, Edinburgh.
1905. ‡Turner, Dr. G. 54 Government-buildings, Pretoria.
1894. *Turner, H. H., M.A., D.Sc., F.R.S., F.R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1905. ‡Turner, Rev. Thomas. St. Saviour's Vicarage, 50 Fitzroy-street, W.
1886. *Turner, Thomas, M.Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham. Springfields, Tipland-road, Selly Hill, Birmingham.
1863. *Turner, Sir William, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E. (President, 1900; Pres. H, 1889, 1897), Principal of the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1890. *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1907. §Tutton, A. E. H., M.A., D.Sc., F.R.S. 41 Ladbroke-square, W.
1886. *Twigg, G. H. Ludgate-hill, Birmingham.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1907. §Twyman, F. 75a Camden-road, N.W.
1865. §Tylor, Edward Burnett, D.C.L., LL.D., F.R.S. (Pres. H, 1884; Council, 1896–1902), Professor of Anthropology in the University of Oxford. Museum House, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.

Year of Election.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1903. ‡Underwood, Captain J. C. 60 Scarisbrick New-road, Southport.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick, W.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892; Council, 1892–99.) 7 Palace Gate-mansions, Kensington, W.
1902. §Ussher, R. J. Cappagh House, Cappagh, Co. Waterford.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.
1905. ‡Uttley, E. A., Electrical Inspector to the Rhodesian Government, Bulawayo.

1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1905. ‡Van der Byl, J. A. P.O., Irene, Transvaal.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1865. *VARLEY, S. ALFRED. Arrow Works, Jackson-road, Holloway, N.
1907. §Varley, W. Mansergh. 21 St. Clair-terrace, Edinburgh.
1903. ‡Varwell, H. B. 2 Pennsylvania-park, Exeter.
1907. §Vaughan, Arthur, B.A., D.Sc., F.G.S. 9 Pembroke-vale, Clifton, Bristol.
1895. §Vaughan, D. T. Gwynne. Botanical Laboratory, The University, Glasgow.
1905. ‡Vaughan, E. L. Eton College, Windsor.
1881. §VELEY, V. H., M.A., D.Sc., F.R.S. 20 Bradmore-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1904. *Vernon, H. M., M.A., M.D. 22 Norham-road, Oxford.
1896. *Vernon, Thomas T. Shotwick Park, Chester.
1896. *Vernon, William. Shotwick Park, Chester.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1906. *VINCENT, J. H., M.A., D.Sc. L.C.C. Paddington Technical Institute, Saltram-crescent, W.
1899. *VINCENT, Professor SWALE, M.B. Physiological Laboratory, University of Manitoba, Winnipeg, Canada.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1902. §Vinycomb, T. B. Riverside, Holywood, Co. Down.
1904. §Volterra, Professor Vito. Regia Universita, Rome.

1904. §Wace, A. J. B. Pembroke College, Cambridge.
1902. ‡Waddell, Rev. C. H. The Vicarage, Saintfield.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T., F.R.S., F.L.S. (Pres. K, 1905.) Hendre, Horsforth-lane, Far Headingley, Leeds.
1900. ‡Wagstaff, C. J. L., B.A. Grafton House, Oundle.
1902. ‡Wainwright, Joel. Finchwood, Marple Bridge, Stockport.
1906. ‡Wakefield, Charles. Heslington House, York.
1905. §Wakefield, Captain E. W. Stricklandgate House, Kendal.
1894. ‡WALFORD, EDWIN A., F.G.S. 21 West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. The Cottage, Whitchurch, Tavistock.
1893. §Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.

Year of Election.

1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.
1901. *Walker, Archibald, M.A., F.I.C. 7 Crown-terrace, Glasgow.
1897. *WALKER, B. E., D.C.L., F.G.S. (Local Sec. 1897.) Canadian Bank of Commerce, Toronto, Canada.
1904. §Walker, E. R. Nightingales, Adlington, Lancashire.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1905. ‡Walker, G. M. Lloyd's-buildings, Burg-street, Cape Town.
1894. *WALKER, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Meteorological Office, Simla, India.
1897. ‡Walker, George Blake. Tankersley Grange, near Barnsley.
1906. ‡Walker, J. F. E. Gelson, B.A. 45 Bootham, York.
1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
1906. §Walker, Dr. Jamieson. 61 Mill Hill-lane, Derby.
1907. §Walker, Philip F., F.R.G.S. 36 Prince's-gardens, S.W.
1888. ‡Walker, Sydney F. 1 Bloomfield-crescent, Bath.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. (Pres. D, 1876; Council, 1870–72.) Broadstone, Wimborne, Dorset.
1905. ‡Wallace, R. W. 2 Harcourt-buildings, Temple, E.C.
1901. ‡Wallace, William, M.A., M.D. 25 Newton-place, Glasgow.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. (Pres. I, 1907.) 32 Grove End-road, N.W.
1905. §Waller, Mrs. 32 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A., 5 Belvoir-terrace, Cambridge.
1895. ‡WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, W.
1894. *WALMISLEY, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1903. ‡Walsh, W. T. H. Toynbee Hall, Whitechapel, E.
1895. ‡WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1902. *Walter, Miss L. Edna. 38 Woodberry-grove, Finsbury Park, N.
1904. *Walters, William, jun. Etheldreda House, Exning, Newmarket.
1904. ‡Ward, A. H. M., B.A. Lenoxvale, Belfast.
1887. ‡WARD, A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1880. *Ward, J. Wesney. 19 Beechfield-road, Catford, S.E.
1874. ‡Ward, John, J.P., F.S.A. Beesfield, Farningham, Kent.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1905. ‡Warlow, Dr. G. P. 15 Hamilton-square, Birkenhead.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. ‡Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1887. ‡WARREN, Lieut.-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres. E, 1887.) Athenæum Club, S.W.
1875. *WATERHOUSE, Major-General J. Hurstmead, Eltham, Kent.
1905. §Watermeyer, F. S., Government Land Surveyor, P.O. Box 973, Pretoria, South Africa.
1904. ‡Waters, A. H., B.A. 48 Devonshire-road, Cambridge.
1900. ‡Waterston, David, M.D., F.R.S.E. 23 Colinton-road, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. 2 Countess-road, Nuneaton.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.

Year of Election.

1901. *WATSON, ARNOLD THOMAS, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1906. §Watson, D. M. S. 466 Moss-lane East, Manchester.
1892. §Watson, G., M.Inst.C.E. Stonegate, Pool, near Leeds.
1885. ‡Watson, Deputy Surgeon-General G.A. Hendre, Overton Park, Cheltenham.
1906. *Watson, Henry Angus. 3 Museum-street, York.
1889. ‡Watson, John, F.I.C. P.O. Box 1026, Johannesburg, South Africa.
1905. ‡Watson, Dr. R. W. Ladysmith, Cape Colony.
1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones House, Beckermet, Cumberland.
1901. §Watt, Harry Anderson. Ardenslate House, Hunter's Quay, Argyllshire.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. The Red House, Bemerton, Salisbury.
1873. *WATTS, W. MARSHALL, D.Sc. Shirley, Venner-road, Sydenham, S.E.
1883. *WATTS, W. W., M.A., M.Sc., F.R.S., Sec.G.S. (Pres. C, 1903; Council, 1902–), Professor of Geology in the Royal College of Science, London, S.W.
1870. §Watts, William, F.G.S. Kenmore, Wilmslow, Cheshire.
1905. ‡Way, E. J. Post Office, Benoni, Transvaal.
1905. §Way, W. A., M.A. The College, Graaf Reinet, South Africa.
1905. ‡Webb, Miss Dora. Gezina School, Pretoria.
1907. §Webb. Wilfred Mark. Odstock, Hanwell, W.
1891. ‡Webber, Thomas. 12 Southey-terrace, Wordsworth-avenue, Roath, Cardiff.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Jahnstrasse 5, Karlsruhe.
1903. ‡Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1890. *WEISS, F. ERNEST, D.Sc., F.L.S., Professor of Botany in the Victoria University, Manchester.
1905. ‡Welby, Miss F. A. Hamilton House, Hall-road, N.W.
1902. ‡Welch, R. J. 49 Lonsdale-street, Belfast.
1894. ‡Weld, Miss. 119 Iffley-road, Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.
1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1881. *WENLOCK, The Right Hon. Lord, G.C.S.I., G.C.I.E., K.C.B., LL.D. Escrick Park, Yorkshire.

Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.

1864. *Were, Anthony Berwick. Roslyn, Walland's Park, Lewes.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1900. §WEST, WILLIAM, F.L.S. 26 Woodville-terrace, Horton-lane, Bradford.
1903. §Westaway, F. W. 1 Pemberley-crescent, Bedford.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.

Year of Election.

1904. §Weymouth, E. S., M.A. 27 Southampton-street, Strand, W.C.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
1893. *WHETHAM, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. Hammerwood Lodge, East Grinstead, Sussex.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council, 1890–96.) 3 Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡WHITE, A. SILVA. (ASSISTANT-SECRETARY.) Burlington House, W.
1904. ‡White, H. Lawrence, B.A. 2 St. Margaret's-terrace, Cheltenham.
1885. *White, J. Martin. Balruddery, Dundee.
1905. ‡White, Miss J. R. Huguenot College, Wellington, Cape Colony.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. (Pres. G, 1899; Council, 1897–1900.) Cedarcroft, Putney Heath, S.W.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1904. ‡WHITEHEAD, J. E. L., M.A. (Local Sec. 1904.) Guildhall, Cambridge.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1905. §Whiteley, Miss M. A., D.Sc. Royal College of Science, S.W.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 5 Bagnall-street, West Bromwich.
1907. *Whitley, E. Clovelly, Sefton Park, Liverpool.
1905. *Whitmee, Harold Babington. Care of India Rubber Co., Ltd., 213 West-street, Durban, Natal.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
1896. §Whitney, Colonel C. A., J.P. 28 Croxteth-road, Liverpool.
1897. ‡WHITTAKER, E. T., M.A., F.R.S., Royal Astronomer of Ireland and Andrews' Professor of Astronomy in the University of Dublin. The Observatory, Dunsink, Co. Dublin.
1901. ‡Whitton, James. City-chambers, Glasgow.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. Alpha Villa, Southwood, Ramsgate.
1905. ‡Whyte, B. M. Simon's Town, Cape Colony.
1905. ‡Wibberley, C. Beira and Mashonaland Railways, Umtali, South Africa.
1881. *Wigglesworth, Robert. Ashtead Lodge, Surrey.
1878. ‡Wigham, John R. Albany House, Mankstown, Dublin.
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.
1887. *WILDE, HENRY, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1905. ‡Wiley, J. R. Kingsfold, Mill-street, Cape Town.
1905. ‡Wilkins, R. F. Thatched House Club, St. James's-street, S.W.
1904. §Wilkinson, Hon. Mrs. Dringhouses Manor, York.
1900. ‡Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1903. ‡Willett, John E. 3 Park-road, Southport.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.W.
1861. *Williams, Charles Theodore, M.V.O., M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.

Year of Election.

1905. §Williams, Gardner F. 2201 R-street, Washington, D.C., U.S.A.
1883. ‡Williams, Rev. H. Alban, M.A. Sheering Rectory, Harlow, Essex.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1891. §Williams, J. A. B., M.Inst.C.E. The Hurst, Branksome Park, Bournemouth.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.
1901. *Williams, Miss Mary. 6 Sloane-gardens, S.W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1883. ‡Williams, T. H. 27 Water-street, Liverpool.
1877. *Williams, W. Carleton, F.C.S. Broomgrove, Goring-on-Thames.
1906. ‡Williams, W. F. Lobb. 32 Lowndes-street, S.W.
1857. ‡Williamson, Benjamin, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1894. *Williamson, Mrs. Janora. Ardoyne, Birkbeck-road, Muswell Hill, N.
1895. ‡Willink, W. (Local Sec. 1896.) 14 Castle-street, Liverpool.
1895. ‡Willis, John C., M.A., F.L.S., Director of the Royal Botanical Gardens, Peradeniya, Ceylon.
1896. ‡Willison, J. S. (Local Sec. 1897.) Toronto, Canada.
1859. *Wills, The Hon. Sir Alfred. Saxholm, Basset, Southampton.
1899. §Willson, George. Ivanhoe, Combermere-road, St. Leonards-on-Sea.
1899. §Willson, Mrs. George. Ivanhoe, Combermere-road, St. Leonards-on-Sea.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1886. ‡*Wilson, Alexander B. Holywood, Belfast.*
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. United Free Church Manse, North Queensferry.
1905. §Wilson, A. W. P.O. Box 24, Langlaagte, South Africa.
1907. §Wilson, A. W. 20 Westcott-street, Hull.
1903. ‡Wilson, C. T. R., M.A., F.R.S. Sidney Sussex College, Cambridge.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1904. §Wilson, Charles John, F.R.G.S. Deanfield, Hawick, Scotland.
1904. §Wilson, David, M.D. Grove House, Paddock, Huddersfield.
1900. **Wilson, Duncan R. Menethorpe, Malton.*
1847. *Wilson, F. Linford. 99 Albany-street, N.W.
1903. ‡Wilson, George. The University, Leeds.
1895. ‡Wilson, Dr. Gregg. Queen's College, Belfast.
1901. ‡Wilson, Harold A., M.A., D.Sc., F.R.S., Professor of Physics in King's College, London. 3 & 4 Clement's Inn, Strand, W.C.
1902. *Wilson, Harry, F.I.C. 32 Westwood-road, Southampton.
1879. ‡Wilson, Henry J. 255 Pitsmore-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1905. ‡*Wilson, J. F. H.M. Dockyard Extension, Simon's Town, Cape Colony.*
1865. ‡Wilson, Ven. Archdeacon James M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1901. *Wilson, Joseph. Hillside, Avon-road, Walthamstow, N.E.
1905. ‡Wilson, Dr. R. Arderne. Saasveld House, Kloof-street, Cape Town.

Year of
Election

1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. §Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., D.Sc., F.R.S. Daramona, Streete, Rathowen, Ireland.
1907. §Wimperis, H. E. 28 Rossetti Garden-mansions, S.W.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., President of Queen's College, Cork.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1905. §Wiseman, J. G., F.R.C.S., F.R.G.S. Stranraer, St. Peter's-road, St. Margaret's-on-Thames.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–1903.) 21 Delahay-street, Westminster, S.W.
1905. ‡Wood, A., jun. Emmanuel College, Cambridge.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1875. *Wood, George William Rayner. Singleton Lodge, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, W.C.; and 16 Leinster-square, Bayswater, W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1904. *Wood, T. B., M.A., Professor of Agriculture in the University of Cambridge. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James. 266 George-street, Glasgow.
1899. *Woodcock, Mrs. E. M. Pahargoomiah Tea Association, Bagdoora P.O., viâ Sillguri, North Bengal, India.
1896. *WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
1888. *Woodiwiss, Mrs. Alfred. 121 Castlenau, Barnes, S.W.
1906. §Woodland, W. N. F. University College, Gower-street, W.C.
1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. ‡Woods, Henry, M.A. St. John's College, Cambridge.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *WOODWARD, ARTHUR SMITH, LL.D., F.R.S., F.L.S., F.G.S. (Council, 1903–), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. The Lindens, St. Mary's-road, Harborne, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council, 1887–94.) 13 Arundel-gardens, Notting Hill, W.
1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, S.W.
1894. *Woodward, John Harold. 8 Queen Anne's gate, Westminster, S.W.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡Worth, J. T. Oakenrod Mount, Rochdale.
1904. §WORTHINGTON, A. M., C.B., F.R.S., Professor of Physics in the Royal Naval Engineering College, Devonport. Mohuns, Tavistock.
1855. *Worthington, Rev. Alfred William, B.A. Old Swinford, Stourbridge

Year of Election.

1906. ‡WRAGGE, R. H. VERNON. York.
1896. ‡Wrench, Edward M., F.R.C.S. Park Lodge, Baslow, Derbyshire.
1905. ‡Wrentmore, G. G. Marva, Silwood-road, Rondebosch, Cape Colony.
1906. ‡Wright, Sir A. E., M.D., D.Sc., F.R.S. 7 Lower Seymour-street, W.
1905. ‡Wright, Allan. Struan Villa, Gardens, Cape Town.
1883. *Wright, Rev. Arthur, D.D. Queens' College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1905. *Wright, FitzHerbert. The Hayes, Alfreton.
1874. ‡Wright, Joseph, F.G.S. 4 Alfred-street, Belfast.
1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. University College, Toronto, Canada.
1904. ‡Wright, R. T. Goldieslie, Trumpington, Cambridge.
1903. ‡Wright, William. The University, Birmingham.
1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1902. ‡Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1901. ‡Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. ‡Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1899. ‡WYNNE, W. P., D.Sc., F.R.S., Professor of Chemistry in the University of Sheffield. 106 Whitham-road, Sheffield.

1905. ‡Yallop, J. Allan. Alandale, London-road, Sea Point, Cape Colony.
1901. *Yapp, R. H., M.A., Professor of Botany in University College, Aberystwyth.
. *Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1905. ‡Yerbury, Colonel. Army and Navy Club, Pall Mall, S.W.
1886. *YOUNG, A. H., M.B., F.R.C.S. (Local Sec. 1887), Professor of Anatomy in the Victoria University, Manchester.
1904. ‡Young, Alfred. Selwyn College, Cambridge.
1891. §Young, Alfred C., F.C.S. 17 Vicar's-hill, Lewisham, S.E.
1905. §Young, Professor Andrew, M.A., B.Sc. South African College, Cape Town.
1894. *Young, George, Ph.D. Lauraville, Bradda, Port Erin, Isle of Man.
1876. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1905. ‡Young, Professor R. B. Transvaal Technical Institute, Johannesburg.
1885. ‡YOUNG, R. BRUCE, M.A., M.B. 8 Crown-gardens, Dowanhill, Glasgow.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road Dublin.
1907. *Young, W. H., M.A., Sc.D., F.R.S. 44A Wilhelm-Weberstrasse Göttingen, Germany.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1903. §Yoxall, J. H., M.P. 67 Russell-square, W.C.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, D.C., U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18.)
1881. Professor G. F. Barker. 3909 Locust-street, Philadelphia, U.S.A.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor E. van Beneden, D.C.L. 50 quai des Pécheurs, Liège, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. 75 rue de Vaugirard, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette-place, New York, U.S.A.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D., LL.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Christiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale University, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim, Germany.
1894. Emile Cartailhac. 5 rue de la Chaine, Toulouse, France.
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1894. Dr. A. Chauveau. 7 rue Cuvier, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, D.C., U.S.A.
1873. Professor Guido Cora. Via Goito 2, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, D.C., U.S.A.
1901. Dr. Yves Delage. Paris.
1872. Professor G. Dewalque. 17 rue de la Paix, Liège, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 4 quai Marcellis, Liège, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor H. Elster. Wolfenbüttel, Germany.

Year of Election.

1894. Professor T. W. W. Engelmann, D.C.L. Neue Wilhelmstrasse 15, Berlin, N.W.
1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1886. Dr. Otto Finsch. Altewiekring, No. 19b, Braunschweig, Germany.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.
1872. W. de Fonvielle. 50 rue des Abbesses, Paris.
1901. Professor A. P. N. Franchimont. Leiden, Netherlands.
1894. Professor Léon Fredericq. 20 rue de Pitteurs, Liège, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague, Bohemia.
1892. Professor Dr. Gustav Fritsch. Dorotheenstrasse 35, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1866. Dr. Gaudry. 7 bis rue des Saints Pères, Paris.
1901. Professor Dr. H. Geitel. Wolfenbüttel, Germany.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, U.S.A.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, U.S.A.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1889. A. Gobert, 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass, U.S.A
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1893. Professor Paul Heger. 23 rue de Drapiers, Brussels.
1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, New York, U.S.A.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R.I., U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1876. Dr. W. J. Janssen. Villa Polar, Massagno, Lugano, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. Annapolis, Maryland, U.S.A.
1887. Professor C. Julin. 153 rue de Fragnée, Liège.
1876. Dr. Giuseppe Jung. Bastions Vittoria 41, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tokyo, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 186–7, Wilmersdorf, bei Berlin.
1896. Professor F. Kohlrausch. Marburg, Germany.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1894. Maxime Kovalevsky. 13 Avenue de l'Observatoire, Paris, France.
1887. Professor W. Krause. Knesebeckstrasse, 17/1, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. Universität, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelmstrasse 108, Breslau.
1887. Professor J. W. Langley. 2037 Geddes-avenue, Ann Arbor, Michigan, U.S.A.
1872. M. Georges Lemoine. 76 rue Notre Dame des Changes, Paris.

Year of Election.

1901. Professor Philipp Lenard. Schlossstrasse 7, Heidelberg.
1887. Professor A. Lieben. IX. Wasagasse 9, Vienna.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I. Munich.
1877. Dr. M. Lindemann. Sennorrstrasse 62, II, Dresden.
1887. Professor Dr. Georg Lunge. Rämistrasse 56, Zurich, V.
1871. Professor Jacob Lüroth. Mozartstrasse 10, and Universität, Freiburg-in-Breisgau, Germany.
1894. Professor Dr. Otto Maas. Universität, Munich.
1887. Henry C. McCook, D.D., Sc.D., LL.D. 3700 Chestnut-street, Philadelphia, U.S.A.
1867. Professor Mannheim. 1 Boulevard Beauséjour, Paris.
1887 Dr. C. A. von Martius. Voss Strasse 8, Berlin, W.
1890. Professor E. Mascart, Membre de l'Institut. 176 rue de l'Université, Paris.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, U.S.A.
1894. Professor G. Mittag-Leffler. Djursholm. Stockholm.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1897. Professor E. W. Morley, LL.D. West Hartford, Connecticut, U.S.A.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico, Via S. Maria, Pisa, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
1890. Maffeo Pantaleoni. 13 Cola di Rienzo, Rome.
1895. Professor F. Paschen. Universität, Tübingen.
1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a/Main, Germany.
1901. Hofrath Professor A. Penck. Georgenstrasse 34–36, Berlin, N.W. 7.
1890. Professor Otto Pettersson. Stockholms Hogskola, Stockholm.
1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1886. Professor F. W. Putnam. Harvard University, Cambridge, Massachusetts, U.S.A.
1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1897. Professor Dr. C. Richet. 15 rue de l'Université, Paris, France.
1896. Dr. van Rijckevorsel. Parklaan 3, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massachusetts, U.S.A.
1895. Professor Karl Runge. Goldgraben 20, Göttingen, Germany.
1901. Gen.-Major Rykatchew. Central Physical Observatory, St. Petersburg.
1894. Professor P. H. Schoute. The University, Groningen, Netherlands.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1892. Dr. Maurits Snellen. Apeldoorn, Pays-Bas, Holland.
1887. Professor H. Graf Solms. Botanischer Garten, Strassburg.
1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.

Year of Election.

1889. Professor G. Stefanescu. Strada Verde 8, Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. Weyderstrasse 9, Breslau.
1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
Arminius Vambéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor Dr. J. H. van't Hoff. Uhlandstrasse 2, Charlottenburg, Berlin.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.
1886. Professor Jules Vuylsteke. 21 rue Belliard, Brussels, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor Dr. Leonhard Weber. Moltkestrasse 60, Kiel.
1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.
1887. Dr. H. C. White. Athens, Georgia, U.S.A.
1881. Professor H. M. Whitney. Branford, Conn., U.S.A.
1887. Professor E. Wiedemann. Erlangen.
1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Dr. Otto N. Witt. Ebereschen-Allée 10, Westend bei Berlin, N.W. 23.
1876. Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.
1887. Professor C. A. Young. Hanover, New Hampshire, U.S.A.
1896. Professor E. Zacharias. Botanischer Garten, Hamburg.
1887. Professor F. Zirkel. Thalstrasse 33, Leipzig.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

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——, The Museum.
Cambridge Philosophical Society.
Cardiff, University College.
Chatham, Royal Engineers' Institute.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Royal Albert Memorial College Museum.
Glasgow, Royal Philosophical Society of.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Institute of Science.
——, Philosophical and Literary Society of.
Liverpool, Free Public Library.
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——, The University.
London, Admiralty, Library of the.
——, Royal Anthropological Institute.
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——, Civil Engineers, Institution of.
——, Geological Society.
——, Geology, Museum of Practical.
——, Greenwich, Royal Observatory.
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——, King's College.
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London, London Institution.
——, Mechanical Engineers, Institution of.
——, Meteorological Office.
——, Physical Society.
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Geographical Society.
——, Royal Institution.
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——, Municipal School of Technology.
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Nottingham, The Free Library.
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——, Radcliffe Observatory.
Plymouth Institution.
——, Marine Biological Association.
Salford, Royal Museum and Library.
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Southampton, Hartley Institution.
Stonyhurst College Observatory.
Surrey, Royal Gardens, Kew.
——, National Physical Laboratory (Observatory Department).
Swansea, Royal Institution of South Wales.
Yorkshire Philosophical Society.
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Dorpat, Russia University Library.
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Helsingfors ...University Library.
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Modena ......Royal Academy.
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Paris.........Association Française pour l'Avancement des Sciences.
—— ....Geographical Society.
—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ......Imperial Observatory.
Rome ....Accademia dei Lincei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
Roumania ..Roumanian Association for the Advancement of Science.
St. Petersburg.University Library.
—— ....Imperial Observatory.
Stockholm ...Royal Academy.
Turin ....Royal Academy of Sciences.
Upsala ......Royal Society of Science.
Utrecht ......University Library.
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—— ....Central Anstalt für Meteorologie und Erdmagnetismus.

ASIA.

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—— ....Grant Medical College.
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—— ....Hooghly College.
Calcutta .....Medical College.
—— ....Presidency College.
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Madras ......The Observatory.
—— ....University Library.
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Kingston	Queen's University.
Manitoba	Historical and Scientific Society
——	The University.
Massachusetts	Marine Biological Laboratory, Woods Holl.
Mexico	Sociedad Cientifica 'Antonio Alzate.'
Missouri	Botanical Garden.
Montreal	Council of Arts and Manufactures.
——	McGill University.
New York	American Society of Civil Engineers.
——	Academy of Sciences.
Ottawa	Geological Survey of Canada.
Philadelphia	American Philosophical Society.
——	Franklin Institute.
——	University of Pennsylvania.
Toronto	The Observatory.
——	The Canadian Institute.
——	The University.
Washington	Bureau of Ethnology.
——	Smithsonian Institution.
——	The Naval Observatory.
——	United States Geological Survey of the Territories.
——	Library of Congress.
——	Board of Agriculture.

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——	The Royal Geographical Society.
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——	Australian Museum.
Tasmania	Royal Society.
Victoria	The Colonial Government.

NEW ZEALAND.

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Wellington	New Zealand Institute.

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